

# Taking a managed adaptive approach to flood risk management planning – evidence for guidance

 Steven Trehwella, Nicola Wilson, Pippa van Kuijk, Teresa Fenn, Rivelin Bridge and Risk & Policy Analysts, June 2022

DOI: [<to be inserted>](#)

## 1 Executive Summary

### 1.1 Background and research aims

Scottish Government guidance strongly encourages managed adaptive flood risk management, stating: Flood risk management planning should be forward looking, acknowledge that future climate change risk is uncertain, promote managed adaptive planning as a means for dealing with this uncertainty, and endorse (through HM Treasury's Green Book) the use of real options analysis for appraising climate sensitive investments.

However, none of the schemes in the 2016-2021 delivery cycle incorporate adaptive plans or reference multiple climate change scenarios. To address this in the next investment cycle, the Flood Risk Management Plans (published in December 2021<sup>1</sup>) have introduced a requirement for adaptation plans to be produced in some areas. SEPA and the Scottish Government are also looking to publish guidance for local authorities responding to the five critical barriers identified in CXC research "Taking a managed adaptive approach to flood risk management planning in Scotland"<sup>2</sup>.

This new research is designed to inform the future guidance by investigating how local authorities are currently developing adaptive flood risk management plans. The four aims of this research are to:

1. identify the data and expertise required to identify trigger points within adaptive flood risk management plans;
2. consider to what extent the relevant data and expertise is available and/or accessible in developing plan options;
3. propose how data and expertise gaps may be filled, and
4. suggest how findings under 2, and proposals under 3, may be incorporated into guidance.

---

<sup>1</sup> <https://www2.sepa.org.uk/frmplans/>

<sup>2</sup> <https://www.climateexchange.org.uk/media/4014/cxc-taking-a-managed-adaptive-approach-to-flood-risk-management-planning-in-scotland.pdf>

The intention is the future guidance will help local authorities embed adaptive approaches and in doing so support the resilience of people and places to a changing and uncertain climate, and create greater long-term value and societal benefits.

The findings of this research will support the Scottish Government, stakeholders and communities in delivering the Flood Risk Management (Scotland) Act 2009, the Scottish Climate Change Adaptation Programme (SCCAP) and a green recovery from Covid-19; through enhanced place-making and designing climate resilient places that meet the needs of people today and in the future.

## 1.2 Case studies selection and research methodology

The three case studies included in this research; Outer Hebrides coastal adaptation, Moray fluvial adaptation, and The Clyde tidal adaptation, were selected based on:

- the availability of project case studies using a managed adaptive approach and exploring the use of triggers to plan current flood risk management investments; and
- the willingness of participants to contribute and share their experience.

Finding suitable case studies for this research was challenging due to the limited uptake of a managed adaptive approach in Scotland. There are numerous projects exploring local climate adaptation, but the number of projects adopting adaptation pathways and exploring trigger points as part of a flood risk management planning process is limited.

In this context, the selected case studies are breaking new ground, and the individuals involved must be commended for a willingness to openly share their early stage learning and experience of piloting a managed adaptive approach. Although the available choices were limited, the selected case studies cover a good range of situations and contexts including:

- flood risk sources (tidal, coastal, fluvial and pluvial);
- environments (island coastal communities, town and city environments);
- scale (local and regional);
- drivers (social, environmental and economic); and
- governance arrangements.

The research methodology involved a scoping and literature review to inform interview design, two stages of semi structured interviews for of each the case studies, case study write-up and exploration of insights against the research aims and key themes, namely:

- Getting started
- Framing of adaptation
- Data and evidence
- Skills and expertise
- Triggers and pathways

Recommendations and conclusions were then document to support the development of guidance and provide practical insights.

## 1.3 Recommendations for guidance

To support Local Authorities in making a shift to a managed adaptive approach to flood risk management planning it is recommended that the future SEPA guidance addresses 12 key aspects:

- Flood resilience and climate adaptation
- Learning and innovation
- Working definitions and principles
- Framing and local ambitions
- Outcomes-based planning
- Co-design, collaboration and engagement
- Designing for uncertainty
- Data and evidence
- Decision points and triggers
- Grey, green and soft measures
- Business case development, and
- Monitoring and evaluation

Furthermore, this research highlights the importance of the ‘getting started and framing’ phase and involvement of stakeholders. To set adaptation investments up for success, it is therefore recommended (regardless of the approach adopted) that step 1 of the process is positioned as a readiness assessment and includes five core activities:

1. **Define ambitions, success and value** – ambitions should be co-designed with stakeholders and include a local definition of resilience (now and in the future).
2. **Plan the adaptation process** – co-design of the process and approach with stakeholders.
3. **Funding and finance** – initial assessment of the potential funding and financing opportunities reflecting the adaptation ambitions and wider local, regional and national strategies, policies and plans.
4. **Monitoring and evaluation** - drawing on the statement of ambitions and definition of resilience an initial assessment of indicator needs and data availability should be completed.
5. **Capacity building and learning** - an initial assessment of the capacity and capabilities of the project partners should be undertaken to determine resource, expertise and skills needs. This assessment should consider the importance of fulfilling four key design roles: systems thinker, leader and story-teller, designer and maker, and connector and convenor.

## 1.4 Conclusions

This research demonstrates that managed adaptive approaches to flood risk management in Scotland are far from mainstream; and the limited number of suitable case studies is evidence that emerging practice is not yet keeping pace with policy ambitions for a more forward-looking approach that recognises future climate uncertainties within decision making and investment practices.

The three case studies explored in this research, illustrate the concept of a managed adaptive approach although not widely in use, is flexible enough to support a range of local circumstances and applications, including: asset-orientated, stakeholder-orientated and transformation-orientated adaptation ambitions and investments. All participants interviewed for this research expressed value in the practice, and in the learning and insights gained from making use of and piloting the approach; and each case study team is looking to make further use of a managed adaptive approach to support future collaboration, and help establish a clear narrative for future actions and investment.

Although guidance is recognised as important to embedding a managed adaptive approach to flood risk management, it is also clear that guidance by itself will not be sufficient to rapidly scale practice. Funding and resources will also be necessary for managed adaptive practices to be adopted at scale, and have an impact within the life-time of the six year flood risk management investment cycle (2022-2027).

It is valuable to recognise that the three case studies have not found the emerging nature of the practice an unsurmountable barrier to making progress. The case studies demonstrate the value of “learning by doing” which in itself is a core aspect of taking a managed adaptive approach to flood risk management planning, and important to scaling up future activity and promoting successes.

## Glossary

**Adaptation** – The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustments to expected climate and its effects. (*Source: IPCC 2014*<sup>3</sup>)

**Incremental adaptation:** Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.

**Transformational adaptation:** Adaptation that changes the fundamental attributes of a system in response to climate and its effects.

**Adaptive management** - process of iteratively planning, implementing and modifying strategies for managing resources in the face of uncertainty. Note – Adaptive management involves adjusting approaches in response to observations of their effects and changes in the system brought on by resulting feedback effects and other variables. (*Source: BS8631:2021*<sup>4</sup>)

**Adaptation Pathways (APs)** – series of adaptation choices involving trade-offs between short-term and long-term goals and values (Note: These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid maladaptation). (*Source: BS8631:2021*)

**Indicators** – specific and measurable metrics which are objectively verifiable and can be tracked over time. (*Source: Literature review on an adaptive approach to flood and coastal risk management, Environment Agency, FRS19221*<sup>5</sup>)

**Resilience** – The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning and transformation. (*Source: IPCC 2014*)

**Theory of Change (ToC)** – is a methodology for planning, participation, adaptive management, and evaluation that is used by [organisations] to promote social change. Theory of Change defines long term goals and then maps backward to identify necessary preconditions (*Source: Wikipedia*) [and describe how and why a desired change is expected to happen in a particular context]. (*See Appendix E for more detail*)

**Threshold** – point beyond which a system is deemed to be no longer effective (economically, socially, technologically or environmentally). (Note: Thresholds can also be known as tipping points beyond which a system can tip into an undesirable state) (*Source: BS8631:2021*)

**Triggers** – used for monitoring and occur when conditions change or are likely to change to an extent that they approach a threshold or tipping point. (*Source: Literature review on an adaptive approach to flood and coastal risk management, Environment Agency, FRS19221*)

<sup>3</sup> [https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-TS\\_FINAL.pdf](https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-TS_FINAL.pdf)

<sup>4</sup> <https://standardsdevelopment.bsigroup.com/projects/2019-00219#/section>

<sup>5</sup>

[https://assets.publishing.service.gov.uk/media/606ef21fe90e076f5589bb7d/Evidence\\_to\\_support\\_an\\_adaptive\\_approach\\_to\\_flood\\_and\\_coastal\\_risk\\_management\\_-\\_report.pdf](https://assets.publishing.service.gov.uk/media/606ef21fe90e076f5589bb7d/Evidence_to_support_an_adaptive_approach_to_flood_and_coastal_risk_management_-_report.pdf)

# Contents

<b>1</b>	<b>Executive Summary</b> .....	<b>1</b>
1.1	Background and research aims .....	1
1.2	Case studies selection and research methodology .....	2
1.3	Recommendations for guidance .....	2
1.4	Conclusions .....	3
<b>2</b>	<b>Introduction</b> .....	<b>7</b>
2.1	Background .....	7
2.2	Research aims .....	7
2.3	Structure of the report .....	8
<b>3</b>	<b>Methodology</b> .....	<b>8</b>
3.1	Overview .....	8
3.2	Scoping .....	9
3.3	Literature review .....	10
3.4	Case study selection .....	10
3.5	Case study interviews .....	10
3.6	Exploring insights .....	11
3.7	Outputs and deliverables .....	11
3.8	Research limitations .....	11
<b>4</b>	<b>Literature review findings</b> .....	<b>11</b>
4.1	Defining a managed adaptive approach .....	11
4.2	Terminology for tipping and trigger points .....	12
4.3	Identification of trigger points .....	12
4.4	Adaptation pathway approaches .....	13
4.5	Monitoring triggers for adaptation planning .....	14
<b>5</b>	<b>Case studies</b> .....	<b>17</b>
5.1	Overview of the case studies and selection process .....	17
5.2	Outer Hebrides coastal adaptation .....	18
5.3	Moray fluvial adaptation .....	20
5.4	Clyde tidal adaptation .....	22
<b>6</b>	<b>Key insights</b> .....	<b>24</b>
6.1	Getting started .....	24
6.2	Framing of adaptation .....	25
6.3	Data and evidence .....	25
6.4	Skills and expertise .....	26
6.5	Triggers and pathways .....	27
<b>7</b>	<b>Recommendations for guidance</b> .....	<b>32</b>
<b>8</b>	<b>Conclusions</b> .....	<b>35</b>
	References .....	37
	Appendix A Interview topic guides .....	38
	Appendix B Outer Hebrides coastal adaptation .....	43
	Appendix C Moray fluvial adaptation .....	48
	Appendix D Clyde tidal adaptation .....	50
	Appendix E Theory of Change .....	54

## Figures

- Figure 1 Description of the research approach and methodology
- Figure 2 Determining tipping points and when those tipping points might be reached  
(extract from Vivid Economic Report (Hiller et al, 2019))
- Figure 3 Theory of change applied to adaptation pathways decision making

Figure 4 Indicative process for developing a monitoring and evaluation framework for adaptation

#### Tables

Table 1	Summary of research aims
Table 2	Indicator categories and examples from New York, informed by NPCC1 (2010) report, Chapter 7 Indicators and Monitoring
Table 3	Beneficial indicator characteristics (Extracted from NPCC1 (2010) Report)
Table 4	Alignment of the research aims, interview themes and case studies
Table 5	Outer Hebrides case study summary
Table 6	Moray case study summary
Table 7	Clyde case study summary
Table 8	Indicator categories and examples
Table 9	Recommended aspects to be addressed in guidance
Table 10	Recommended Step 1 in adaptation process (Readiness Assessment)

## 2 Introduction

### 2.1 Background

Scottish Government guidance strongly encourages managed adaptive flood risk management stating: flood risk management planning should be forward looking, acknowledge that future climate change risk is uncertain, promote managed adaptive planning as a means for dealing with this uncertainty, and endorse (through HM Treasury's Green Book) the use of real options analysis for appraising climate sensitive investments.

However, none of the schemes in the 2016-2021 delivery cycle incorporate adaptive plans or reference multiple climate change scenarios. To address this in the next investment cycle, the Flood Risk Management Plans (published in December 2021<sup>6</sup>) have introduced a requirement for adaptation plans to be produced in some areas, and SEPA and Scottish Government are looking to publish guidance for local authorities responding to the five critical barriers identified in CXC research "Taking a managed adaptive approach to flood risk management planning in Scotland"<sup>7</sup>.

These barriers include lack of a standardised methodology for adaptive planning. This research aims to respond to this lack of standardised methodology, focusing on the design and identification of trigger points as a key step in the creation of adaptive plans. The research draws on areas where local authorities are currently developing adaptive plans and piloting the use of adaptation pathways.

International practice<sup>8</sup> shows that successful investment decision making related to adaptive flood risk management is not independent of place-based socio-economic-political drivers and uncertainties. To support future investment cycles, it is therefore important this research, and future guidance, reflects the cross-sectoral and contextual nature of climate change resilience; and numerous changes in the Scottish policy environment that include:

- the new Infrastructure Assessment Framework part of A Blueprint for Scotland;
- 'Water-Resilient Places – A Policy Framework for Surface Water Management and Blue-Green Infrastructure';
- Scotland's Fourth National Planning Framework Position Statement;
- the National Performance Framework (and Place Standard Tool); and
- new industry standards on adapting to climate change such as ISO14090 and BS8631.

The findings of this research will support the Scottish Government and partners in delivering the Flood Risk Management (Scotland) Act 2009, the Scottish Climate Change Adaptation Programme (SCCAP) and a green recovery from Covid-19; through enhanced place-making and designing climate resilient places that meet the needs of people today and in the future.

### 2.2 Research aims

This research is designed to investigate how local authorities are currently developing adaptive flood risk management plans, focusing on their approach to the design and identification of trigger points as a key step. Specifically, this research explores the four aims set-out in *Table 1* to provide insights for future guidance to be published by SEPA in 2022.

<sup>6</sup> <https://www2.sepa.org.uk/frmplans/>

<sup>7</sup> <https://www.climatechange.org.uk/research/projects/taking-a-managed-adaptive-approach-to-flood-risk-management-planning-in-scotland/>

<sup>8</sup> <https://www.climatechange.org.uk/research/projects/international-practice-on-assessing-investment-needs-and-securing-investment-to-adapt/>

Table 1: Summary of the research aims

#	Research aim
1	Identify the data and expertise required to identify trigger points within adaptive flood risk management plans.
2	Consider to what extent the relevant data and expertise is available and/or accessible in developing plan options.
3	Propose how data and expertise gaps may be filled.
4	Suggest how findings under 2, and proposals under 3, may be incorporated into guidance.

The intention is that the SEPA guidance will help local authorities, stakeholders and communities to embed adaptive approaches, and in doing so support the resilience of people and places to a changing and uncertain climate, and create greater long-term value and societal benefits.

## 2.3 Structure of the report

This report is structured to align with the research methodology and research aims. *Section 3.0* describes the research methodology and the approach to case study selection and interviews. *Section 4.0* describes the literature review and key insights related to the design and identification of trigger points.

*Section 5.0* summarises the three case studies setting-out: the background and framing of local ambitions; the approach being taken to the design of triggers and adaptation measures; and opportunities and lessons for other local authorities.

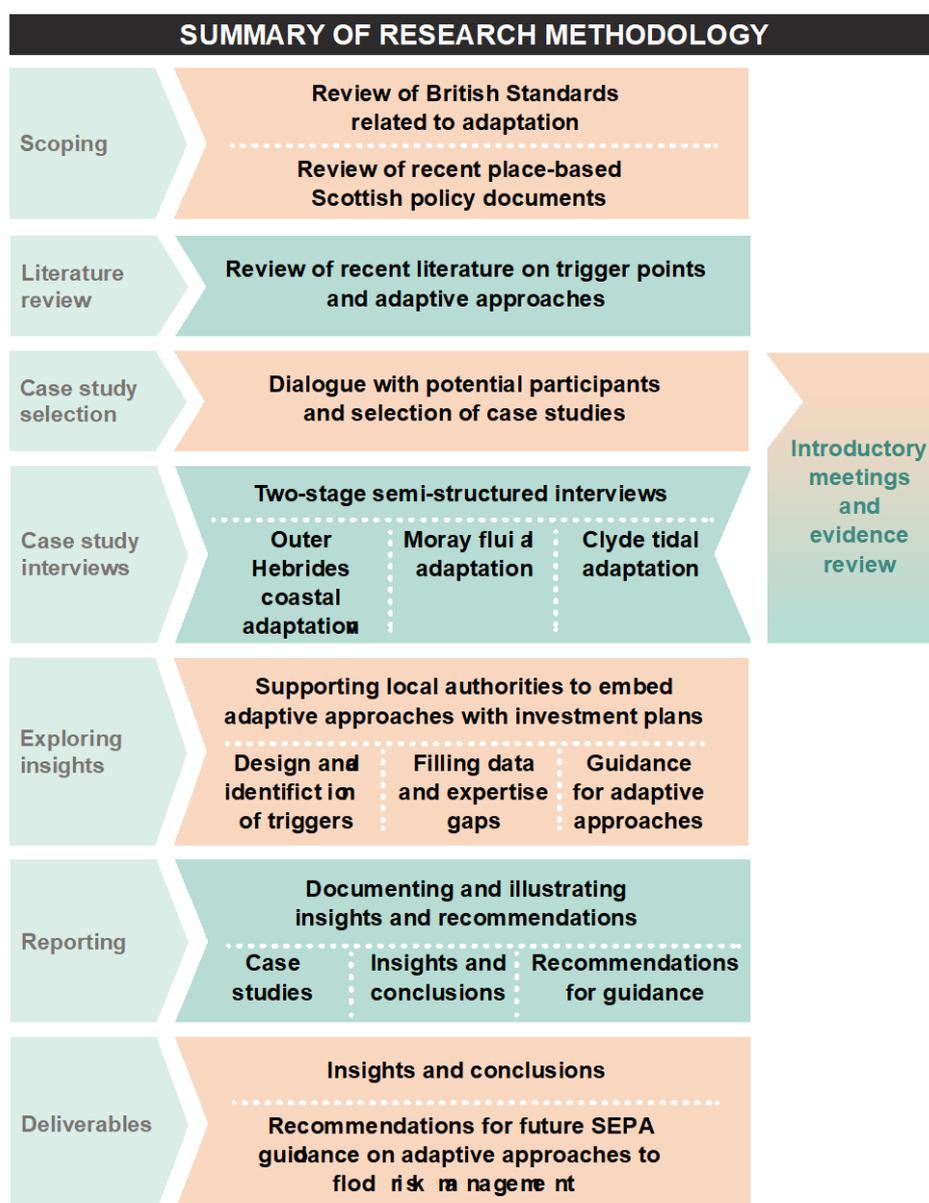
*Section 6.0* explores the case studies to identify insights into managed adaptive approaches and how guidance can support future uptake of the practice. *Section 7.0* then sets out recommendations related to the use, identification and design of triggers; the filling of data and expertise gaps; and the development of guidance for adaptive approaches to flood risk management planning in Scotland. *Section 8.0* summarises the research conclusions.

# 3 Methodology

## 3.1 Overview

This research was informed by best practice in adaptive approaches and builds on previous ClimateXChange research. The research methodology centres around three case studies selected to cover a variety of contexts for the application of adaptive approaches, and adaptation pathways, to flood risk management investment planning. *Figure 1* summarises the methodology and workflow. The following sub-sections provide more detail on the approach taken.

Figure 1: Description of the research approach and methodology



### 3.2 Scoping

To explore the research aims, and identify adaptive management topics and themes to support the design of the interview topic guides, the most recent British Standards related to adaptation were reviewed:

- BS EN ISO 14090:2019 Adaptation to climate change. Principles, requirements and guidelines
- BS EN ISO 14091:2021 Adaptation to climate change. Guidelines on vulnerability, impacts and risk assessment
- ISO/TS 14092:2020 Adaptation to climate change. Requirements and guidance on adaptation planning for local governments and communities.
- BS 8631:2021 Adaptation to climate change. Using adaptation pathways for decision making.

A desk-based review of recent place-based policy documents in Scotland was also completed to provide an understanding of adaptation drivers and priorities. From these document reviews, and the parallel literature review (*Section 3.3*), eight adaptive

management themes were identified to support interview design. The themes explore slightly wider than the four research aims to ensure the adaptation investment ambitions and local decision making context are reflected in the research. The eight themes are described in Section 3.5.

### 3.3 Literature review

To explore definitions of triggers and tipping points a review of relevant recent literature was undertaken to capture and compare definition of trigger points and tipping points. The google search term: 'trigger points' AND 'adaptive pathways' OR 'adaptation' was used to search for relevant literature. The first 8 relevant returns were reviewed (*See references for details*).

The ClimateXChange report “Taking a managed adaptive approach to flood risk management planning in Scotland” (2019), and the PIANC publication “Climate change adaptation planning for ports and inland waterways” (2020)<sup>9</sup> were also included as relevant sources of interest. The literature review findings are described in *Section 4.0*.

### 3.4 Case study selection

Case studies in this research were selected based on:

- the availability of project case studies using a managed adaptive approach and exploring the use of triggers to plan current flood risk management investments; and,
- the willingness of participants to contribute and share their experience.

The three case studies selected cover tidal, coastal and fluvial flood risk investments at a range of scales, a range of different socio-economic-environmental drivers and vulnerabilities; and diverse project initiation and governance arrangements.

*Section 5.1* describes the contextual differences between the case studies; and provides commentary and insights arising from the selection process.

### 3.5 Case study interviews

Two-stage semi-structured interviews were undertaken for each case study based on the 4 research aims, and 8 themes drawn from the scoping and literature reviews:

- |  |                                      |
|--|--------------------------------------|
| 1. Framing of objectives and ambitions | 5. Adaptation measures and actions   |
| 2. Place-making and co-benefits        | 6. Design of triggers and thresholds |
| 3. Participation and engagement        | 7. Monitoring and evaluation         |
| 4. Scenarios                           | 8. Opportunities and lessons learnt  |

The approach to the interviews was exploratory, examining how local authorities are currently developing adaptive flood risk management plans and their experience of the process reflecting on challenges and how these were overcome; and their insights, achievements and anticipated next steps.

The stage 1 interviews explored the context and local ambitions with the lead participant for each of the case studies focusing on themes 1-4. The stage 2 interviews were undertaken with the lead participant and 3 additional stakeholders per case study. The stage 2 interviews focused on themes 5-8 to exploring the participants experience of designing and implementing adaptive approaches. A summary of the topic guides for the two interviews is included in *Appendix A*.

The interview findings have been captured in *Section 5.0* and Appendices B-D.

<sup>9</sup> <https://www.pianc.org/publications/envicom/wg178>

### 3.6 Exploring insights

To support local authorities with adaptive investment planning, the three case studies were then explored to identify insights, conclusions and recommendations for the development of guidance. Insights were explored against the research topics: data and evidence, skills and expertise, triggers and pathways. Two additional topics emerged from the case studies and were explored due to their significance in understanding how managed adaptive approaches are being used in practice; the two additional topics are: framing of adaptation and getting started. The key insights are set out in *Section 6.0*.

### 3.7 Outputs and deliverables

The outputs of this research are designed to:

- provide insight on how local authorities are approaching and piloting the application of adaptive flood management practices and use of triggers to develop investment plans;
- the challenges experienced, including data and expertise gaps, and how these are being overcome; and
- recommendations to SEPA for incorporating insights into future guidance.

The primary audience for this research is the Scottish Government and SEPA, and the wider flood risk management sector.

### 3.8 Research limitations

Managed adaptive approaches to flood risk management planning are contextual to local social, economic and environment drivers, and local sensitivities, risks and vulnerabilities. The case studies explored in this research provide a good starting point for exploring adaptive approaches in a range of contexts. However, the research is limited to three case studies that are all at the early stage of investment planning.

## 4 Literature review findings

### 4.1 Defining a managed adaptive approach

This research builds on the previous ClimateXChange research “Taking a managed adaptive approach to flood risk management in Scotland”<sup>10</sup>. That report describes a managed adaptive approach as:

*“A managed adaptive approach is a plan for managing flood risk, made up of a series of actions that might be taken at various points in time. The flexibility built into such a managed plan allows flood risk management measures to adjust efficiently as the future unfolds and more information on risk becomes available.”*

The recently published British Standard “Adaptation to climate change – using adaptation pathways for decision making – Guide” (2021) frames the concept of a managed adaptive approach more widely as both a process and a plan, adopting the following definitions.

**Adaptive management** *“process of iteratively planning, implementing and modifying strategies for managing resources in the face of uncertainty. Note – Adaptive management*

---

<sup>10</sup> <https://www.climateexchange.org.uk/media/4014/cxc-taking-a-managed-adaptive-approach-to-flood-risk-management-planning-in-scotland.pdf>

*involves adjusting approaches in response to observations of their effects and changes in the system brought on by resulting feedback effects and other variables”.*

**Adaptation pathways (APs)** “series of adaptation choices involving trade-offs between short-term and long-term goals and values. Note – These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid potential maladaptation”.

The related British Standard publication “Adaptation to climate change – Requirements and guidance on adaptation planning for local governments and communities” (2020), also emphasises that: *“It is important to note that the climate is changing, and planning and implementation is a continual learning and improvement process that requires sustained attention and action”.*

This research has adopted the framing of a managed adaptive approach as both an investment decision making process and a plan, with continual learning and improvement being central to the approach.

## 4.2 Terminology for tipping and trigger points

Central to a managed adaptive approach (and adaptation pathways) are tipping points, described as the point at which an action is required to meet the system objective. A range of terminology is used to refer to trigger and tipping points and associated adaptive pathways terms highlighting the need for consistency within the field for a common understanding.

Adaptive pathways are a way of developing long term climate adaptation plans for a place often looking to the end of the century and beyond. Allison et al., (2021) describe pathways as being “linked to specific **thresholds** or ‘**tipping points**’ where a change to our understanding of the impacts of climate change, the local environment or other socio-economic conditions may require further adaptive action”. As well as tipping points (or **thresholds**), **indicators** are defined to observe trends and changes in the system to derive **signals** (for example, when a threshold is reached that indicates an adaptation tipping point may be reached soon). **Signals** could support decision making related to: additional research, implementation of follow-up actions in an adaptation plan, and making adjustments to the adaptation pathways.

Within the Dynamic Adaptive Policy Pathways (DAPP) approach to adaptive planning, **signals** provide the early warning of the emergence of the **trigger (decision-point)** and the trigger initiates the process to change pathway before a harmful adaptation-threshold is reached (Stephens et al, 2018). Ideally the monitoring system gives **signals** before a decision needs to be taken to implement actions (Haasnoot et al, 2019). According to Haasnoot et al (2019), **signals** “could be related not only to impacts but also to driving forces, such as trends and events in the physical environment, human-driven impacts on the system, technological developments, or changes in societal values and perspectives”.

Bosomworth et al (2015) and Coulter (2019) additionally identify **turning points** as thresholds found in socio-political systems that may be reached indicating an adaptation threshold such as changes in climate, policy objectives or social values. Haasnoot et al (2019) also mention **opportunity tipping points** of actions which are the point at which a particular action becomes feasible or attractive, for example because of lower costs of actions or technical developments.

## 4.3 Identification of trigger points

Previous work undertaken by Vivid Economics (2019) for ClimateXChange on taking a managed adaptive approach in Scotland recommends an approach based on the DAPP

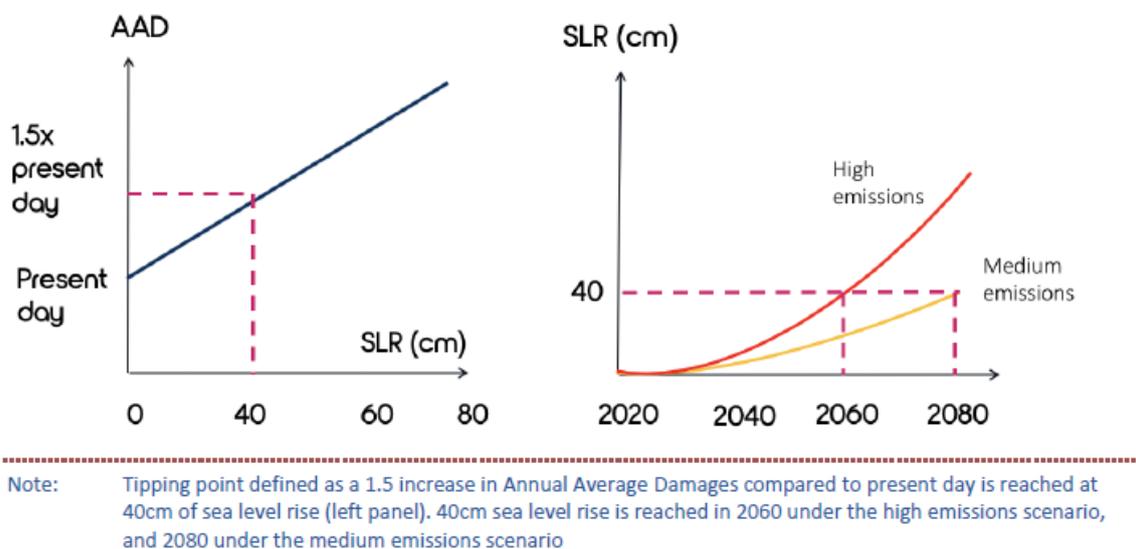
methodology for identifying trigger points for adaptation planning using a 3-step process (and *Figure 2*):

1. engage with the community to identify an ‘acceptable’ level of risk, expressed in Average Annual Damages (AAD);
2. assess climate risks under various scenarios to identify tipping points at which AAD exceeds the acceptable level; and
3. account for intervention lead times and planning cycles to specify trigger points at which decisions may need to be taken to avoid unacceptable levels of risk.

Engagement with stakeholder and communities is recommended to determine acceptable levels of risk in a vulnerable area. The Vivid approach to identifying tipping points is based on physical/climatic systems using SEPA/Met Office information to monitor when thresholds might be exceeded. The definition of trigger horizons is recommended to be matched approximately to the potential timings of breaches of tipping points but should also align with points in planning cycles at which decisions are made and account for lead times between these decisions, the implementation of any intervention, and the consequent increase in protection.

This approach can be suitable to a well understood system where long-term data sets are available and there are limited changes or interactions to consider. However, in a complex fluvial system with multiple interactions and limited hydrological data this approach will be more challenging.

Figure 2: Determining tipping points and when those tipping points might be reached (extracted from Vivid Economics report (Hiller et al, 2019))



It is not the intention of this report to present the above example of tipping point design as a definitive methodology. The example is provided here as a starting point for the consideration of trigger and threshold design explored in this report.

#### 4.4 Adaptation pathway approaches

Based on a literature review by Werners et al (2021) of conceptual and applied adaptation studies, three types of adaptation clusters (approach) were identified each with a different desired outcome:

1. **performance-threshold orientated** –meeting short and long-term adaptation needs;
2. **multi-stakeholder oriented** – promoting collaborative learning, adaptive planning and adaptive capacity; and

### 3. **transformation-oriented approaches** – accounting for complexity and long-term change including a potential need for transformation

Each adaptation approach can be considered to be suitable for different types of situations and contexts depending on the goals for the system and the existing context.

**Performance-threshold orientated pathways** visualise alternative sequences of discrete adaptation measures in response to different future scenarios. This approach is appropriate to future adaptation in a defined system of interest, with a clear adaptation goal and in a data-rich context where goals can be quantified. They are based on the idea that the performance of the current system is satisfactory and so adaptation actions are triggered by performance dropping below an acceptable level. Examples include Thames2100 and the DAPP methodology based on risk adaptation, where the adaptation is visualised with a pathways map and scorecard system measuring performance criteria under rising sea levels in order to maintain performance under different climate scenarios.

**Multi-stakeholder pathways** place an emphasis on the social and institutional components of the adaptation process. They include multiple drivers and multiple stakeholders with conflicting goals, interest and values. These approaches focus on participatory methods in the development of pathways and aim to promote collaborative learning and build adaptive capacity. The Eyre Peninsula, South-western Australia has taken a regional planning process in their adaptive planning involving a wide cross-section of stakeholders and participatory methods to identify pathway options.

In contrast to the other approaches, **transformation orientated pathways** do not assume that the current system performance is satisfactory. Instead, they seek to develop pathways towards a future goal or vision and transform through focusing on the root cause of vulnerabilities to enable adaptation. It is suggested that this approach is most suited to dynamic, multi-driver contexts where a potential need for transformation has already been identified. New York City is an case example of a transformation orientated pathway taking a holistic and mission-based approach towards resilience by tackling the root cause of vulnerability and creation of an aspirational future vision.

These three approaches should not be seen as independent from each other and could potentially be used together at different stages of a specific investment journey. For instance an investment might start with a multi-stakeholder orientated approach to enhance adaptive capacity and define outcomes, and then move to a performance-threshold or transformation-orientated approach at a later stage.

Furthermore, the three approaches should not be taken as definitive or restrictive. The practice of adaptation pathways is flexible and equally able to accommodate other outcome-orientated approaches, which could include wider environmental, social or technological drivers.

## 4.5 Monitoring triggers for adaptation planning

There are still major challenges to be addressed in the design of a monitoring and evaluation system that is capable of early detection of tipping points in situations with large natural variability (Bloeman et al, 2018). In practice, tipping points and pathways are often first defined and developed qualitatively according to expert judgment before more intensive model-based quantitative investigations are carried out (Haasnoot et al, 2019).

Various approaches are proposed to assist in developing a monitoring and evaluation system for an adaptive management approach. Haasnoot et al (2018) include a five-step plan aiming to assist the user to identify multiple, measurable trigger points that give timely signals for tipping points:

1. What are key decisions, actions, tipping points and assumptions in the adaptive plan?

2. What developments could trigger implementation of the actions or invalidity of the assumptions?
3. What (derivative) signposts can be used to monitor these developments and assumptions and give signals that actions need to be implemented or that the plan may need to be reassessed?
4. If these signposts are measurable, are they able to give timely and reliable signals for implementation or reassessment of the plan?
5. What combination of signposts could give timely, reliable and convincing signals and will be selected for the monitoring plan?

As risk is not directly observable or measurable in most cases, a range of indicators should be monitored to identify risk-based thresholds that can be used as triggers for decision-making (Allison et al, 2021) . Stephens et al (2018) suggest using increases in the frequency of smaller storm-tides to signal the future increase in frequency of large storm tides which could be tied to an adaptation threshold. They propose using less extreme events to trigger adaptation responses rather than incidences of extreme events needing to be reached.

Whilst identifying measurable indicators is important, they also need to be timely and reliable if they are to result in an implementation or reassessment of the plan. Haasnoot et al (2018) describe four considerations for the selection of indicators as part of adaptation planning:

- **Slope:** An indicator that changes gradually will give earlier information compared to one that changes abruptly
- **Signal/noise ratio:** Due to variability of a signal, an average of an indicator value for a large area will have a better signal to noise ratio
- **Statistics:** Timing and reliability of the signal can be assessed with transient scenarios as well as the risk of the false signal
- **Time for implementation and expected timing of signal:** The time between the indicator relative to the moment of a tipping point is important to consider as to whether the indicator provides a suitable time interval for timely implementation

During the development of adaptive pathways approach in New York City as a response to Hurricane Sandy, New York City has assembled a framework for indicator selection to monitor climate change and adaptation to inform their decision making (NPCC1, 2010)<sup>11</sup>. This includes criteria and categories to assist in the selection of appropriate indicators. As adaptation decisions are informed by more than just physical climate, it is proposed that indicators are not based solely on climate data but should also consider social-economic changes such as demographic data and land-use, and advancements in research and evidence of whether adaptation is taking place and where. *Table 2* sets out indicator categories and possible examples of indicators.

Table 2: Indicator categories and examples from New York, informed by NPCC1 (2010) report, Chapter 7: Indicators and Monitoring

Indicator category	Description	Indicators examples
<b>Physical climate change variables</b>	Monitoring the physical climate for climate change trends relative to forecast values	Temperature, precipitation and sea level rise
<b>Risk exposure</b>	Information tracking potential impacts of hazards as well as socio-economic changes	Electrical outages, combined sewer overflows, salt-water intrusion

<sup>11</sup> [NPCC1 \(2010\): Chapter 7 – Indicators and Monitoring](#)

Indicator category	Description	Indicators examples
<b>vulnerability and impacts</b>	indicating change in vulnerability to hazards	
<b>Adaptation measures</b>	To monitor the implementation of adaptation strategies and their effectiveness.	The number of buildings in coastal flood zones, insurance index of infrastructure coping capacity to climate change, number of days with major telecoms outages
<b>New research</b>	Monitor advances in knowledge and scientific progress related to climate change theory, impacts, adaptation strategies and their effectiveness.	Tracking new climate change research findings that may alter future projections and uncertainties and affect adaptation strategies.

For indicators to be appropriate, learning from New York City adaptation planning proposed that indicators need to also be policy relevant, analytically sound and measurable. These characteristics of beneficial indicators are described in *Figure 3*.

Table 3: Beneficial indicator characteristics (Extracted from NPCC1 (2010) Report)

<b>Policy relevance</b>	<ul style="list-style-type: none"> <li>• Provide a representative picture of climate conditions</li> <li>• Measure stakeholder-relevant climate change hazards and society's responses</li> <li>• Be simple, easy to interpret, and able to show trends over time</li> <li>• Be responsive to changes in climate and related human activities</li> <li>• Provide a basis for intra- and intercity comparisons</li> <li>• Have a scope applicable to critical regional climate change issues</li> <li>• Have a baseline, threshold, or reference value or range of values against which to compare, so that users can assess the significance of the values associated with it through time.</li> </ul>
<b>Analytical soundness</b>	<ul style="list-style-type: none"> <li>• Be theoretically well founded in technical and scientific terms</li> <li>• Based on local, national, or international standards with consensus about its validity</li> <li>• Readily linked to economic models, scenario projections, and information systems.</li> </ul>
<b>Measurability</b>	<ul style="list-style-type: none"> <li>• Based on readily available data or data available at a reasonable cost–benefit ratio</li> <li>• Be adequately documented and of known quality</li> <li>• Updated at regular intervals, in accordance with reliable procedures</li> <li>• Of sufficient length in time and numbers to allow a quantitative statistical evaluation of the uncertainties associated with the data.</li> </ul>

Haasnoot et al (2019) propose both ‘bottom-up’ and ‘top-down’ approaches can be used to identify tipping points (and indicators). ‘Bottom-up’ assessments establish unacceptable outcome thresholds before assessing the timing of tipping points, whilst ‘top-down’ approaches use traditional scenario analyses to determine the range and timing of these points. ‘Bottom-up’ approaches can rely on model-based assessments (e.g. stress tests, sensitivity analyses) to establish the failure conditions (thresholds), or these can be specified via expert judgment or stakeholder consultation. Scenarios are then used to assess the timing of the tipping point conditions.

The use of indicators for monitoring flood resilience and adaptation is an emerging practice that is strongly aligned to taking a managed adaptive approach. In designing indicators and triggers it is vital that indicators are meaningful to stakeholders and to take a proportionate approach (in terms of resource commitment) and account for:

- **Trend** – the degree to which indicator can show trends in resilience over time.
- **Accessibility** - ease with which users access and understand the measure, available metadata, illustration and accompanying advice.
- **Data availability** - does the data already exist; if the data does not exist, can it be collected easily by non-specialists; can indicators be selected to reflect differences in context?
- **Impact** – the degree to which the indicator reflects resilience across the five capacities (social, institutional, economic, natural, and physical resilience).

Indicators can be quantitative or qualitative, and in some instances proxy indicators<sup>12</sup> or composite indicators<sup>13</sup> may be easier to capture and monitor. These topics and example indicators are explored in “Measuring Resilience to Flooding and Coastal Erosion – Research, Analysis and Evaluation Report, Environment Agency, April 2022”.

## 5 Case studies

### 5.1 Overview of the case studies and selection process

Finding suitable case studies for this research was challenging due to the limited uptake of a managed adaptive approach in Scotland. There are numerous projects exploring local climate adaptation, but the number of projects adopting adaptation pathways and exploring trigger points as part of a flood risk management planning process is limited. The early stage of development of some of the potential projects explored also made the sharing of lessons either impractical or subject to stakeholder and organisational sensitivities at this point in time.

In this context, the selected case studies are breaking new ground, and the individuals involved must be commended for a willingness to openly share their learning and experience of piloting a managed adaptive approach. Although the available choices were limited, the selected case studies cover a good range of contexts including:

- flood risk sources (tidal, coastal, fluvial and pluvial);
- environments (island coastal communities, town and city environments);
- scale (local and regional);
- drivers (social, environmental and economic); and
- governance arrangements.

The following sub-sections summarise the three case studies:

- Outer Hebrides coastal adaptation;
- Moray fluvial adaptation, and
- The Clyde tidal adaptation.

The Case Studies are set-out to align to the research aims and interview themes as shown in *Table 4*. To enable the case studies to be compared and contrasted it was necessary to explore the place-based context and motivations for the projects. This is captured and described within the ‘framing of ambitions’.

---

<sup>12</sup> A proxy indicator is an indirect sign or measure that can approximate or can be representative of a phenomenon without the presence of a direct sign or measure

<sup>13</sup> A composite indicator is formed when individual indicators are compiled into a single index (Source OECD - <http://stats.oecd.org/glossary/>)

This wider exploration, although not explicitly covered by the four research aims, is essential to understanding a managed adaptive approach, and the relationship between local adaptation drivers and priorities, and the conceptualisation, design and identification of triggers.

Table 4: Alignment of the research aims, interview themes and case studies

Research aims	Interview themes	Case Study Structure (appended)	Key aspects
-	Themes 1-2	Framing of Ambitions	Getting started
			Framing of adaptation
1 and 2	Themes 3-7	Design of triggers and adaptation measures	Data and evidence
			Skills and expertise
			Triggers and pathways
3 and 4	Theme 8	Opportunities and Lessons	Opportunities and Lessons

## 5.2 Outer Hebrides coastal adaptation

Table 5 provides a summary of the Outer Hebrides case study. The full case study is presented in *Appendix B*.

Table 5: Outer Hebrides case study summary

Key aspects	Case study headlines and insights
<b>Getting started</b>	This project was sparked by a desired to declare a climate emergency in the Outer Hebrides. Local stakeholders agreed that rather than declaring a Climate Emergency without a clear action plan the Outer Hebrides Climate Planning Partnership would form a Working Group to develop a clear route-map, plans and targets for climate adaptation. Rather than create targets in isolation from other strategies and plans, the ambition of the Working Group is to embed actions (both mitigation and adaptation) within an update of the Local Outcomes Improvement Plans (LOIP).
<b>Framing of adaptation</b>	<p>Adopting a multi-hazard approach was valuable due to the local interdependencies between the various climate hazards and wider socio-economic-environmental impacts and risks. It was also recognised that the local communities only have a certain capacity to engage and that exploring all hazards together would avoid engagement fatigue and provide a stronger perspective of the 'lived experience' of residents.</p> <p>An important finding was around not treating the Outer Hebrides as a single place. Across the 70 islands there is a significant amount of diversity (social, cultural, physical, environmental, and heritage) and it is important this is reflected in capacity, vulnerability assessment and impacts analysis.</p> <p>Engagement demonstrated that it was important to frame the exercise in terms of current and future risks, and positive current and future aspirations/ ambitions to avoid being alarmist and to fully engage participants in climate conversations.</p> <p>Framing of the work in terms of developing actions to embed in the Local Outcomes Improvement Plan, provided a means for the Community Planning Partnership to drive this initial stage of work and leverage the goodwill of partners. As such the ambition of the partnership is not to create a new adaptation strategy and duplicate other partners activities,</p>

Key aspects	Case study headlines and insights
	rather to embed climate adaptation within existing and future investment strategies and plans.
<b>Data and evidence</b>	<p>A lesson from the project team, is the importance of establishing a shared view of data needs and the definition of evidence; in terms of what is needed, to what level of detail, and when, in order to make commitments and design triggers and thresholds. Tension between individual perspectives, on data and evidence, is seen as a key future challenge to making timely investment decisions.</p> <p>The Outer Hebrides work has shown the value of Climate Impact Interviews, together with community dialogue and participatory mapping, to bring to life the <i>'lived experience'</i> of residents and communities. This evidence base is seen as essential to complementing scientific data and establishing a shared view of <i>'what to hold on to'</i>. The team see this as an important first step in establishing triggers and future thresholds that are meaningful to local people and decision makers.</p> <p>The team also recognised the importance of validating scientific and spatial information through field work and site visits with communities (in their places) to fully understand the relationships between risks, vulnerability and opportunities; and that digital intelligence is not a substitute for professional and local insights on the ground.</p>
<b>Skills and expertise</b>	<p>The team recognise that making adaptive management decisions in the context of uncertainty is a new skill that the Working Group will need to embrace and develop as the project moves forward.</p> <p>The related Climate Beacons for COP26<sup>14</sup> initiative undertaken in the Outer Hebrides<sup>15</sup> was recognised as a valuable approach to engagement; unlocking wider insights at a geographical scale that was meaningful to people. The initiative also added capacity, created strong local networks and out reach across the islands, and brought creative partners into the broader governance and cooperation strategy for climate action, and establish new creative ways of engaging with communities.</p>
<b>Triggers and pathways</b>	<p>At this stage, the process of designing triggers and adaptation measures has not started, however core aspects of their intended approach include:</p> <ul style="list-style-type: none"> <li>○ taking a multi-hazard approach to the assessment of triggers;</li> <li>○ listening to everyone to understand the <i>'lived experience'</i> of the local communities throughout the Outer Hebrides;</li> <li>○ exploring risks, impacts and opportunities at a scale that is meaningful to people and the place;</li> <li>○ designing triggers based on socio-economic-environmental and climate thresholds and an understanding of what communities value and what they want to hold on to;</li> <li>○ embracing both 'risk-based' (climate risks) and 'positive future vision' (local ambitions) perspectives to frame and prioritise future adaptation actions; and</li> <li>○ developing climate stories to support adaptation actions.</li> </ul>
<b>Opportunities and lessons</b>	<p>The project team stressed the importance of the forming process, insomuch that this was a new group, with a new way of working, with a new set of partners, and a new topic (adaptation). For the group to move ahead the team needed to go through some 'learning by doing together' to</p>

<sup>14</sup> <https://www.creativecarbonscotland.com/project/climate-beacons-for-cop26/#Hebrides>

<sup>15</sup> <https://lanthide.org>

Key aspects	Case study headlines and insights
	<p>inform the process and start planning and prioritising an approach that was right for the Outer Hebrides. Not setting a prescriptive terms of reference at the outset was considered important to providing the flexibility to learn and build the necessary networks, partners and connections.</p> <p>To date the Working Group has made progress based on the goodwill, commitment and resources of the project partners. To take the next step it is recognised that additional financial commitment will be necessary and that dedicated resources will be important to move faster and meet the expectations of the local community.</p>

### 5.3 Moray fluvial adaptation

Table 6 provides a summary of the Moray case study. The full case study is presented in Appendix C.

Table 6: Moray case study summary

Key aspects	Case study headlines and insights
<b>Getting started</b>	<p>Moray Council has a long history of responding to fluvial flood risk and has invested over £170 million in flood alleviation schemes since 2014 estimating to prevent damages of £85 million to date. This includes the flood alleviation schemes of Rothes, Elgin and Forres. Due to the significant investment undertaken by Moray Council in delivering these flood alleviation schemes, it is important for them to understand how risk will change in the future as climate change projections increase to maintain the protection provided by the defences.</p>
<b>Framing of adaptation</b>	<p>The current ambition for the adaptive pathways approach is to be able to maintain the original design standard provided by the existing defences with the uncertainty of climate change and understand the tipping points in the system to know when further intervention is required.</p> <p>The approach being developed is equally considered a tool for long-term Council decision making and investment planning, and for effective communication with Elected Members and communities. One perceived benefit of developing adaptation pathways is the creation of visual pathways that help to communicate and create a common understanding across stakeholders of the trajectory they are headed and an understanding of the future potential implications.</p>
<b>Data and evidence</b>	<p>Moray Council is early on in the process of developing adaptation pathways and has developed a 6-step approach:</p> <ol style="list-style-type: none"> <li>1. Discuss rationale</li> <li>2. Identify future levels of risk</li> <li>3. Review levels of risk and changes over time</li> <li>4. Identify triggers</li> <li>5. Develop list of options</li> <li>6. Create a pathway of options over time</li> </ol> <p>The Council is currently undertaking further modelling with consultants to understand the current and future risk under climate change scenarios. This first step will identify what standard of protection is being provided now with updated climate change allowances and at what points in the future that standard of protection may be reduced to understand how assets respond under changing scenarios. As fast response catchments</p>

Key aspects	Case study headlines and insights
	<p>with risk from extreme and high intensity events as well as risk from combined sources, there is a high level of uncertainty in modelling the system.</p> <p>Gaps in knowledge include surface water and fluvial interactions, how the geomorphology will respond to extreme events, and how water abstraction may change in the future and affect water levels. Whilst the systems are gauged, there is only 10 years of data which does not provide a long-term record for future predictions.</p> <p>To develop adaptation options, a long list of adaptive measures have been developed that will be reviewed for viability for each location following finalisation of model outputs. A short list will then be collaboratively developed with stakeholders, affected communities and partners to develop adaptive pathways. Due to the uncertainty in the system described above, it is likely that continued monitoring to build the evidence base will be an early-stage action in the adaptation plan rather than implementation of adaptation measures in the short-term.</p>
<b>Skills and expertise</b>	<p>The intention is to develop the plan and options in-house due to the importance of long-term monitoring of triggers and thresholds, and integration of the plan across the Council. Therefore, building knowledge and understanding of adaptation pathways by in-house officers will create ownership of the adaptive approach. This would be supported by outsourced technical specialists i.e. hydrologists and modellers, to develop the current and future understanding of risk to inform the plan development.</p>
<b>Triggers and pathways</b>	<p>Design and monitoring of triggers is seen as the most challenging step in developing adaptation pathways due to the range of interacting variables involved in a fluvial system. Adaptation pathways are reasonably established for coastal systems, with long records for sea level rise and coastal erosion allowing future forecasts, this is less established for fluvial systems which often have limited data available in comparison. Additionally, there are few examples of adaptation pathways developed for fluvial systems to provide a precedent to draw on.</p> <p>Potential triggers and monitoring approaches have been considered that may be appropriate for the Rothes scheme. The aim is to develop hydrological triggers that are easy and low-cost to monitor and provide insight into the systems thresholds. Whilst these have been not been finalised, the type of indicators being explored include: yearly rainfall averages, frequency of high intensity events, annual river flows, and freeboard allowance.</p> <p>Whilst the focus is on developing hydrological triggers, there is potential and interest to develop socio-economic triggers to feed into master planning. These triggers are likely to be more easily understood and embraced by political members which could help embed the adaptation pathways approach within the Council.</p>
<b>Opportunities and lessons</b>	<p>A number of opportunities from the experiences at Moray Council have been suggested to support the process of adaptive management for fluvial systems particularly with existing defences:</p> <ul style="list-style-type: none"> <li>As there is no single source of guidance available for adaptive management in Scotland, it would be useful to develop a national approach for developing triggers including ideas for types of triggers, the available data and how these can be monitored.</li> </ul>

Key aspects	Case study headlines and insights
	<ul style="list-style-type: none"> <li>• Creating a consistent approach to adaptive management and the design of adaptation pathways would assist procurement of consultants and setting design briefs.</li> <li>• There is value in having opportunities to have more conversations and co-creation with other local authorities about adaptive management to help develop and share ideas.</li> <li>• There is a need for more education and awareness of what adaptive management is. This includes for practitioners to fully understand the process and concept and how to best deliver, as well as non-practitioners such as political members to understand the concept of planning under uncertainty.</li> <li>• As well as awareness raising, there is a need to develop consistent terminology within the field. A common terminology that bridges all adaptation planning areas could create a shared understanding of adaptive management and support collaboration.</li> </ul>

## 5.4 Clyde tidal adaptation

Table 7 provides a summary of the Clyde case study. The full case study is presented in Appendix D.

Table 7: Clyde case study summary

Key aspects	Case study headlines and insights
<b>Getting Started</b>	<p>Glasgow and the Clyde region is at risk from increased flooding due to climate change from surface water, the rivers, and the sea. The Clyde Mission – Clyde Corridor was identified as a National Development in the NPF4 to support the aims of the long term spatial plan for Scotland. The Clyde Mission, announced in January 2020, is a place-making initiative to connect people and places through green transport networks and, deliver renewable energy sources and open areas of land for new development opportunities. The Mission will investigate Glasgow’s climate risk and development risk to inform development planning and enable Glasgow City region to encourage climate informed economic development to prosper for the region. The Adaptation Mission has been set up with the purpose of climate risk identification and development of adaptation planning, to help facilitate these plans. The Adaptation Mission set about in summer 2021 to develop its approach to adaptation. .</p>
<b>Framing of adaptation</b>	<p>The adaptation approach for the Clyde is in its early days. The Adaptation Mission group has set up its framework for delivery, establishing what adaptation means for the Clyde, and how this can be delivered. There is recognition that the existing reactive approach to risk management is not acceptable and needs to be improved. This can be improved through a managed adaptive approach that works with the social, economic and environmental opportunities and constraints of the region to lead to increased resilience to present and future climate change.</p>
<b>Data and evidence</b>	<p>Historically, the understanding of risk from the rivers and the sea has relied upon hydraulic modelling and improvements to the availability and accuracy of modelled data. Over the last two years, the Clyde river model has been reviewed and updated to provide the latest record of risk assessment from the river. This model provides the introduction to the</p>

Key aspects	Case study headlines and insights
	<p>understanding of the physical risk from flooding, and aids the identification of the social, environmental, and economic risk factors associated with flooding. The model outputs also provide the baseline for the identification of the interactions across these influences and a conduit for the communication of future planning recommendations.</p> <p>In the Clyde region adaptation planning geographical area, there is a challenge with the accumulation of data from various sources that are delivered in different formats, timescales, access, and availability. This adds a complexity to data interpretation and communication both within the Clyde Mission and further, across partner organisations.</p>
<b>Skills and expertise</b>	<p>Within the Clyde Adaptation Mission, skilled workers with the enthusiasm and desire to collaborate to achieve, have been brought together. There is acknowledgement that collaboration will enable change and that there is work to be done to develop the governance structure that enables interdisciplinary teams to work together, within and outside the same organisations. Building on this, and the readily available enthusiasm to make change happen, is giving the delivery bodies the time and opportunity to work together. On the scale of the Clyde, the Mission has been working to identify what and how would work best, within the constraints of existing busy day jobs and funding availability. This Mission requires collaboration at a scale that has never been delivered in the Glasgow region.</p>
<b>Triggers and pathways</b>	<p>Traditionally, hydraulic tipping points have been used for the identification of the next steps of interventions. The Mission is seeking an approach that will deliver a balance between the economic, social, environmental and political drivers to generate an acceptable tipping point, or a combination of tipping points that need to be reviewed cumulatively to identify the potential range of interventions. The Mission is also reviewing the approach to defining the acceptable level of risk, providing a 'no regrets' approach and seeking how this can be best communicated effectively to those most severely impacted by risk.</p>
<b>Opportunities and lessons</b>	<ul style="list-style-type: none"> <li>○ Improve identification of how risks translate to wider social, economic, and environmental impacts</li> <li>○ Importance of local coordination of development planning to inform adaptation planning on a regional scale</li> <li>○ Consistency in data delivery across the Clyde region (and more widely) would facilitate ease of interpretation for all parties involved in adaptation planning and delivery</li> <li>○ Utilisation of existing skills, through knowledge sharing, relationship building and the desire to collaborate to achieve, will deliver outcomes</li> </ul>

## 6 Key insights

### 6.1 Getting started

A key insight and an important point of difference between the three case studies was how the projects were initiated. The Outer Hebrides case study was initiated at the community level, sparked by a local desire to declare a climate emergency and develop meaningful adaptation actions for incorporation within the Local Outcomes Improvement Plan. The Moray case study was initiated by local authority officers seeking to future proof existing investments in flood defences and develop an adaptation narrative to support future engagement and investment planning. Finally, the Clyde case study was initiated by the Scottish Government and regional partners, to align ambitions for economic growth with flood risk management and the long-term implications of climate change.

In developing guidance for managed adaptive approaches it will be important to recognise and embrace this flexibility with respect to possible starting points for project initiation; and encourage diversity in terms of: people, leadership, governance, adaptation approaches, skills and levels of knowledge at the initial stages of development.

There is no single starting point, and a flexible approach will best recognise the contextual nature of adaptation and the importance of engagement and local choices from the outset. There are however important core activities that should be undertaken at the start to mobilise the process and get the team/stakeholders ready, these are discussed later in *Section 7.0*, and include defining adaptation ambitions and agreeing a local definition of resilience (now and in the future).

Where the three case studies share something in common, is they have all, to some extent, relied on the goodwill and commitment of people and individuals with the confidence to pilot a new way of working. To leverage goodwill and inspire others to pilot managed adaptive approaches it will be important for guidance to address the question of ‘why’<sup>16</sup> in relation to taking a management adaptive approach, and not simply address the ‘how’.

Setting out key adaptation principles will also be beneficial to establishing a common understanding of a managed adaptive approach and the benefits of using adaptation pathways. The ten principles for good adaptation described by the Climate Change Committee<sup>17</sup> provide a good starting point for this, namely:

1. Set out a vision for a well-adapted UK
2. Integrate adaptation into policies, including for Net Zero.
3. Adapt to 2°C; assess the risk up to 4°C
4. Avoid lock-in
5. Prepare for unpredictable extremes
6. Assess interdependencies
7. Understand threshold effects
8. Address inequalities
9. Consider opportunities from climate change
10. Support the implementation through funding, resources, indicators, and research to link adaptation actions to reductions in risk

<sup>16</sup> Why take a managed adaptive approach (in terms of benefits) is addressed in the “Literature review on an adaptive approach to flood and coastal risk management, Environment Agency, FRS19221 (2021)” Link:

[https://assets.publishing.service.gov.uk/media/606ef21fe90e076f5589bb7d/Evidence\\_to\\_support\\_an\\_adaptive\\_approach\\_to\\_flood\\_and\\_coastal\\_risk\\_management\\_-\\_report.pdf](https://assets.publishing.service.gov.uk/media/606ef21fe90e076f5589bb7d/Evidence_to_support_an_adaptive_approach_to_flood_and_coastal_risk_management_-_report.pdf)

<sup>17</sup> <https://www.theccc.org.uk/wp-content/uploads/2021/07/Independent-Assessment-of-UK-Climate-Risk-Advice-to-Govt-for-CCRA3-CCC.pdf>

The three case studies also recognise that goodwill and guidance will not be sufficient to rapidly scale practice and sustain the necessary level of innovation and pipeline of pilot projects. For managed adaptive approaches to flood risk management to be adopted at scale in Scotland, access to front-end funding and resources will be necessary.

## 6.2 Framing of adaptation

The literature review identified three types of adaptation approaches (Werners et al, 2021): performance-threshold orientated, multi-stakeholder orientated, and transformation orientated. These three approaches were evident in the three selected case studies and their desired outcomes. The three approaches are not mutually exclusive, and all the case studies are seeking to enhance both the coping capacity and adaptive capacity at the local level.

In the case of the Outer Hebrides, the approach reflects the multi-stakeholder orientated approach with collaborative learning and capacity building at the heart of their planning activities. This is reflected in the set-up of their Climate Change Working Group which includes public, civil society, third sector, academia and community representation in the adaptation planning process which embraces climate impact interviews, community dialogue and participatory mapping.

The Moray case study reflects the performance-threshold orientated approach, with a focus on sustaining the standard of protection, and future proofing existing flood defence asset-performance for the long-term. The process is being led by Council Officers with support from external technical expertise in modelling.

Finally, the Clyde case study reflects the transformation oriented approach, starting from the perspective that the existing system is not satisfactory and can be enhanced through a managed adaptive approach to improve social, economic and environment outcomes. The adaptation approach on the Clyde is aligned with the ambition “to make the Clyde an engine of sustainable and inclusive growth, for the city, the region and for Scotland”.

To achieve their ambitions, all the case studies are seeking to work with decision makers to make a case for future investment and deliver adaptation measures on the ground. In each instance, the case for future investment is expected to include the benefits associated with avoiding future flood risks, alongside realising wider co-benefits (social, economic and environmental). In the Outer-Hebrides and the Clyde, the unlocking of wider co-benefits is seen as inherent to the case for investment and stakeholder acceptance.

A significant insight from the case studies is that currently none of the teams are anticipating the output of their work to be a stand-alone plan, rather the intention is to inform or enhance existing investment plans and local strategies. In the case of the Outer Hebrides the intention is to embed mitigation and adaptation actions in the Local Outcomes Improvement Plan. In Moray the intention is to align adaptation plans with wider local strategies and plans, and in the Clyde the intention is to support wider local, regional and national plans, strategies and initiatives that are already underway.

From the case studies it is evident that a managed adaptive approach is of value in a range of contexts and applications. A managed adaptive approach is not one way of working, and to avoid unnecessarily constraining the process it will be important for guidance to encourage a range of approaches, support proportional use of tools and methodologies, foster investment innovation to avoid future flood risk and deliver wider co-benefits, and support systems-thinking and learning.

## 6.3 Data and evidence

All of the projects have started the process of establishing baseline data and evidence to drive investment in resilience and adaptation. A key insight, particularly emphasised by the

Outer-Hebrides case study, is the importance of establishing a shared view of data needs and the definition of evidence. Tension between professional perspectives, on data and evidence, was recognised as a potential barrier to collaboration and timely investment decision making.

To support the practice of making decisions in the context of uncertainty, which is inherent to a managed adaptive approach (and the design of indicators and triggers), the case studies recognised the value of three types of evidence:

1. existing climate and scientific evidence;
2. existing local knowledge, insights and ‘lived experience’, and
3. new evidence that can be created by taking and evaluating adaptation actions.

Existing climate and scientific evidence includes national and regional climate projections and local hydraulic models. This type of evidence is valuable in mapping and assessing risks and impacts.

Local knowledge and insights are complementary to scientific evidence, and valuable to filling knowledge gaps, ground-truthing scientific evidence, and understanding risks and the impacts for communities and stakeholders. Community input at the outset is also valuable to designing indicators that are meaningful at the local level for communities and stakeholders. This is important to the legitimacy of the adaptation process and understanding resilience at the local level.

In other instances where data and evidence do not currently exist, the use of pilot projects is valuable to support learning, understand co-benefits, establish new evidence and test the impact of adaptation measures and actions.

To make cost effective and timely decisions in the context of uncertainty it is valuable to make best use of all three types of evidence; using Type 1 to assess risks and scenarios, Type 2 to understand current and future resilience at the local level, and Type 3 to support learning and future refinement of plans and strategies. The combined use of all three types of evidence can lend confidence to the decision making process and help manage uncertainties.

All three case studies also recognise the importance of making data and evidence meaningful and accessible to stakeholders and decision makers. To achieve this, the project teams are seeking to develop climate stories and adaptation narratives that communicate risks, the impacts and the benefits of action. In each instance, the case studies have more work to do to articulate impacts and the benefits of action.

Finally, the importance of validating scientific and spatial information through field work, site visits and local knowledge was recognised as important to understanding the relationships between risks, vulnerability and opportunities; and that digital intelligence is not a substitute for professional and local insights on the ground.

## 6.4 Skills and expertise

All project teams recognised that a managed adaptive approach is a new and unfamiliar way of working. In particular, it was stressed that ‘making decisions in uncertainty’ is a new and challenging skill set for both the teams developing future solutions and investment cases, and for the investment case assurers and decision makers.

All the case study teams recognised the contextual nature of managed adaptive approaches, and that learning by doing was an important part of their experience of the practice. It was also recognised that guidance could contribute by providing a common language and

definitions, and common framing to ‘what is a managed adaptive approach’. It was further recognised that guidance could support uptake of the approach by describing the benefits to those involved in the process, and the benefit to planning and investment outcomes.

As all the case studies are at an early stage it was challenging for the teams to describe their needs in terms of skills and expertise. However, areas where upskilling of project teams was seen as necessary included:

- Collaboration, governance and working across silos / sectors;
- Data management and data hosting;
- Designing of indicators and triggers, and the associated design of monitoring and evaluation frameworks and systems;
- Business case development, including establishing adaptation costs and benefits;
- Integration of Net Zero (climate mitigation) and adaptation practices; and
- Procuring managed adaptive approaches and outcomes.

All three case studies are drawing upon a mixture of local resources and external expertise and resources to develop their adaptation plans and actions.

It was recognised that due to the place-based nature of adaptation and the need for local commitment and leadership, a managed adaptive approach cannot be simply out-sourced and that building local leadership capacity and adaptation capabilities is essential to the approach.

Within the Outer Hebrides and Clyde case studies diversity of skills, story-telling and systems-thinking were also recognised as important skills. These skills are also reflected in the ClimateXChange research “Tidal Flooding on the Clyde Options Analysis and Scoping of Adaptation Pathways (2022)” which draws on work published by the Design Council<sup>18</sup> to recognise the importance of fulfilling four key design roles: systems thinker, leader and story-teller, designer and maker, and connector and convenor.

## 6.5 Triggers and pathways

At this time, none of the cases studies have explored the design of triggers (and indicators) and pathways in detail. However, all the case studies acknowledge the importance of this and the need to build the skills and capacity to undertake this.

The Outer Hebrides has identified the importance of involving the community in the design of future triggers, choices and pathways; and that climate triggers will need to work hand-in-hand with socio-economic and environmental triggers for decisions to have local meaning. To support community engagement in the development of triggers and future choices, the project is developing ‘local climate stories’ to foster dialogue and insights related to future climate risks, opportunities and decision-points.

In Moray, the project team has started the process and recognise the importance of integrating the design of triggers with a long-term monitoring and evaluation framework. At this time, the team have undertaken an initial assessment of hydrological triggers. Looking ahead, the team are interested to develop socio-economic triggers that can inform master-planning, and be more easily understood and embraced by elected members within the Council.

On the Clyde, the project has not yet explored triggers and indicators. It is clear however, that as the project is taking a transformation-orientated approach to adaptation their triggers and indicators will need to accommodate climate trends and changes, alongside socio-economic and environment trends and changes.

<sup>18</sup> <https://www.designcouncil.org.uk/resources/guide/beyond-net-zero-systemic-design-approach>

The project teams do not have experience of this process, and are looking for support and guidance regarding trigger and indicator design, and how best to establish monitoring and evaluation frameworks to track and communicate changes over time.

Drawing on the literature review and three case studies *Table 8* sets out indicator categories that could be adopted and provides example indicators.

Table 8: Indicator categories and examples

Indicator category	Potential indicators of change
Climate	<ul style="list-style-type: none"> <li>• Change in mean sea level</li> <li>• Change in average annual rainfall</li> </ul>
Vulnerability and impact	<ul style="list-style-type: none"> <li>• Change in estimated average annual flood damage (AAD)</li> <li>• Change in risk to life</li> <li>• Change in flood defence asset condition</li> <li>• Change in environmental asset condition</li> <li>• Change in affordability of insurance</li> </ul>
Adaptation measures	<ul style="list-style-type: none"> <li>• Length of coastal defences upgraded</li> <li>• Area of new saltmarsh</li> <li>• Uptake of flood warning services</li> </ul>
Research and technology	<ul style="list-style-type: none"> <li>• Technological advances (such as early warning systems, or Property Level Resilience products)</li> <li>• Advances in adaptation and green finance</li> </ul>
Policy	<ul style="list-style-type: none"> <li>• Changes in legislation (such as planning and land-use and environmental standards)</li> </ul>
Social	<ul style="list-style-type: none"> <li>• Socio-demographic changes</li> <li>• Community expectations and confidence</li> </ul>

Seven types of adaptation measures (actions) are described in the UK Climate Change Risk Assessment<sup>19</sup>, namely: engineered solutions, nature-based solutions, new or emerging technologies, behavioural, institutional, financial and data/R&D. These could all form the basis for indicators for change or action within an adaptation plan.

Indicator design and potential resilience indicators are explored in detail in “Measuring Resilience to Flooding and Coastal Erosion – Research, Analysis and Evaluation Report, Environment Agency, FRS20288, April 2022”<sup>20</sup>. The Environment Agency research demonstrated the importance of stakeholder participation in the co-design of indicators, and the value of the using the Theory of Change to provide a clear line of sight between the current context, objectives, activities, outcomes and impacts.

Other useful sources of information on indicator design (for tracking changes in resilience and design of indicators) include:

- “A guide to CXC Adaptation Indicators”<sup>21</sup> (2016) which provides a starting point and framework for exploring indicators. The document categorises indicators against natural environment, buildings and infrastructure networks, and society; and relates indicators to the SCCAP and CCRA risk assessment.

<sup>19</sup> <https://www.theccc.org.uk/wp-content/uploads/2021/07/Independent-Assessment-of-UK-Climate-Risk-Advice-to-Govt-for-CCRA3-CCC.pdf>

<sup>20</sup> This research report was developed by JBA Consulting in collaboration with Steven Trehwella of Rivelin Bridge, and Professor Robert Nicholls of the University of East Anglia and the Tyndall Centre. The research is expected to be published in 2022.

<sup>21</sup> [https://www.climatexchange.org.uk/media/1372/cxc\\_adaptationguide\\_hyperlinks.pdf](https://www.climatexchange.org.uk/media/1372/cxc_adaptationguide_hyperlinks.pdf)

- Research by CXC to support the outcomes focus in the second Scotland’s Climate Change Adaptation Programme<sup>22</sup> which builds on the 2016 framework.
- The Flood Resilience Measurement for Communities (FRMC)<sup>23</sup> tool from the Zurich Flood Resilience Alliance which uses the 5C-4R Framework to measure change. The 5C (five capitals) are: human, social, physical, natural and financial. The 4R (four properties of resilient systems) are robustness, redundancy, resourcefulness and rapidity.

The project teams are also seeking guidance on how to link monitoring and evaluation of triggers and indicators, with pathway planning and outcomes. To support this shift to outcome-based decision-making, which is central to a managed adaptive approach, it will be beneficial to embed Theory of Change practice (or similar practices) within the guidance. This is an approach to planning that defines long term goals and then maps backward to identify necessary preconditions. In essence, the Theory of Change, involves considering the proposed inputs (adaptation actions) and the causal link from inputs to expected outputs and outcomes, see *Appendix E* for details. The approach is used in government planning and can be found in the ‘Magenta Book – Central Government guidance on evaluation’ March 2020<sup>24</sup>.

Creating a Theory of Change does not automatically identify indicators for monitoring and evaluation. However, there is a connection between a theory of change and the use of indicators and triggers with adaptation planning, as set out in *Figure 3*.

Monitoring and evaluation is often seen as the final step in a project cycle, for example it comes in at the end of the stepped approach in the British Standard. However, building on the literature review it is important to consider a monitoring and evaluation framework for managed adaptive planning at every stage of an adaptation planning process. *Figure 4* illustrates this, and provides an indicative process for developing a monitoring and evaluation framework for adaptation. Guidance for design of such a process will help teams conceptualise and design indicators to inform actions, outcomes and learning.

The application of a managed adaptive approach to flood risk management planning, the design of triggers and indicators for measuring resilience and adaptation progress, and the use of monitoring and evaluation for adaptation are related and emerging areas of practice. It is valuable therefore to recognise that the three case studies have not found the emerging nature of the practice an unsurmountable barrier to making progress. The case studies demonstrate the value of “learning by doing” which in itself is a core aspect of taking a managed adaptive approach to flood risk management planning.

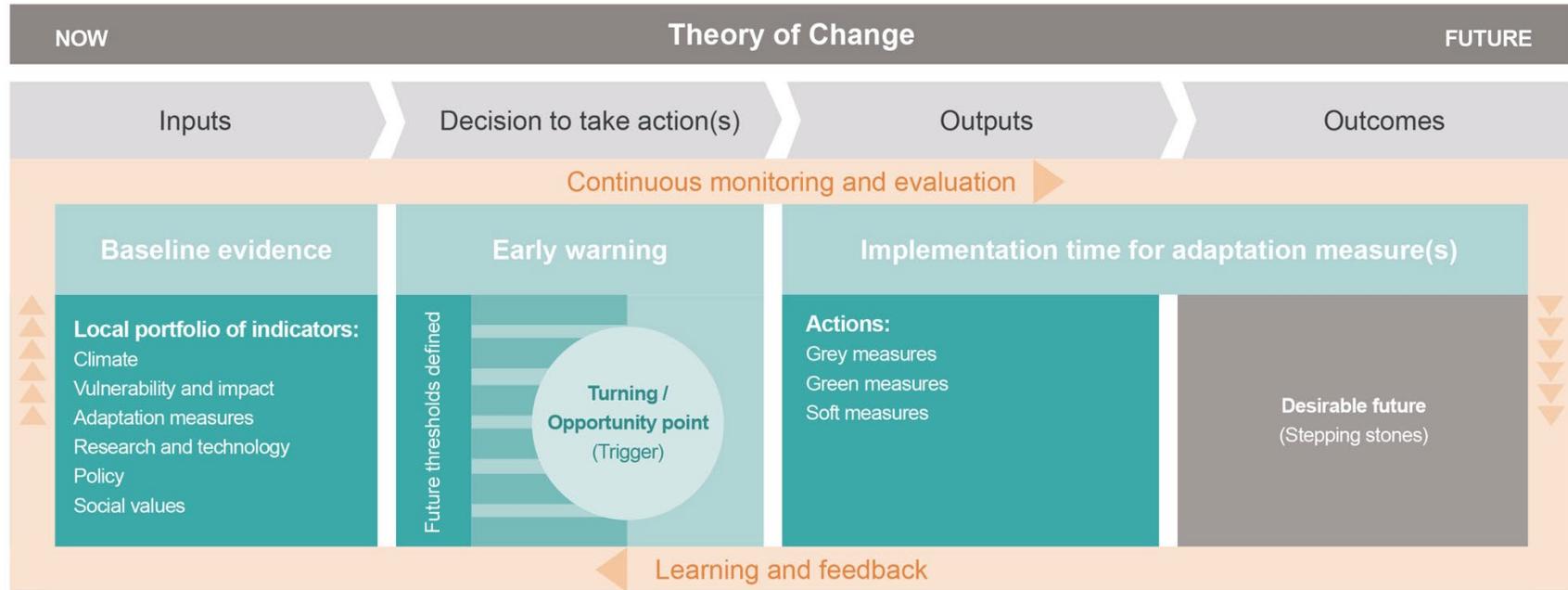
<sup>22</sup> <https://www.climatexchange.org.uk/research/projects/monitoring-and-evaluation/>

<sup>23</sup> [https://www.preventionweb.net/files/53269\\_941pazfrpadhocv7cweb.pdf](https://www.preventionweb.net/files/53269_941pazfrpadhocv7cweb.pdf)

<sup>24</sup>

[https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/879438/HMT\\_Magenta\\_Book.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/879438/HMT_Magenta_Book.pdf)

Figure 3: Theory of change applied to adaptation pathways decision making



Note: any given investment pathway will be made up of a series of steps (changes) combining triggers, actions and learning

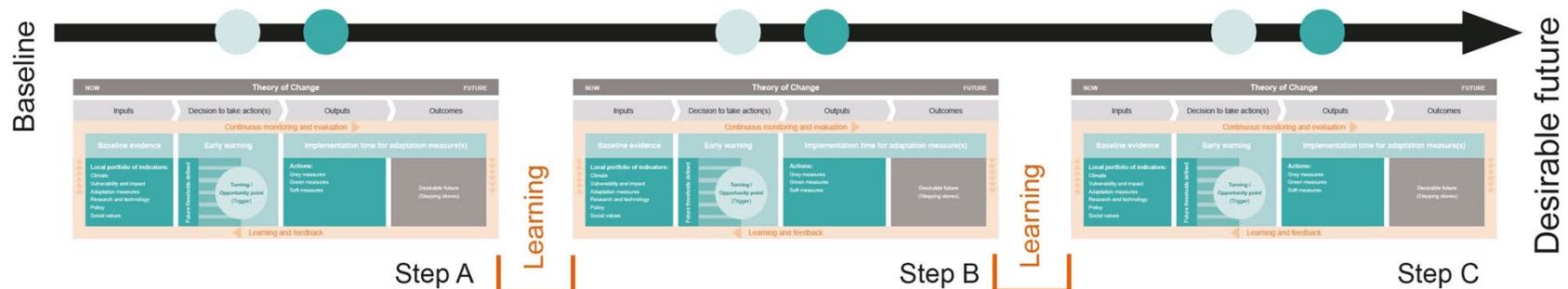
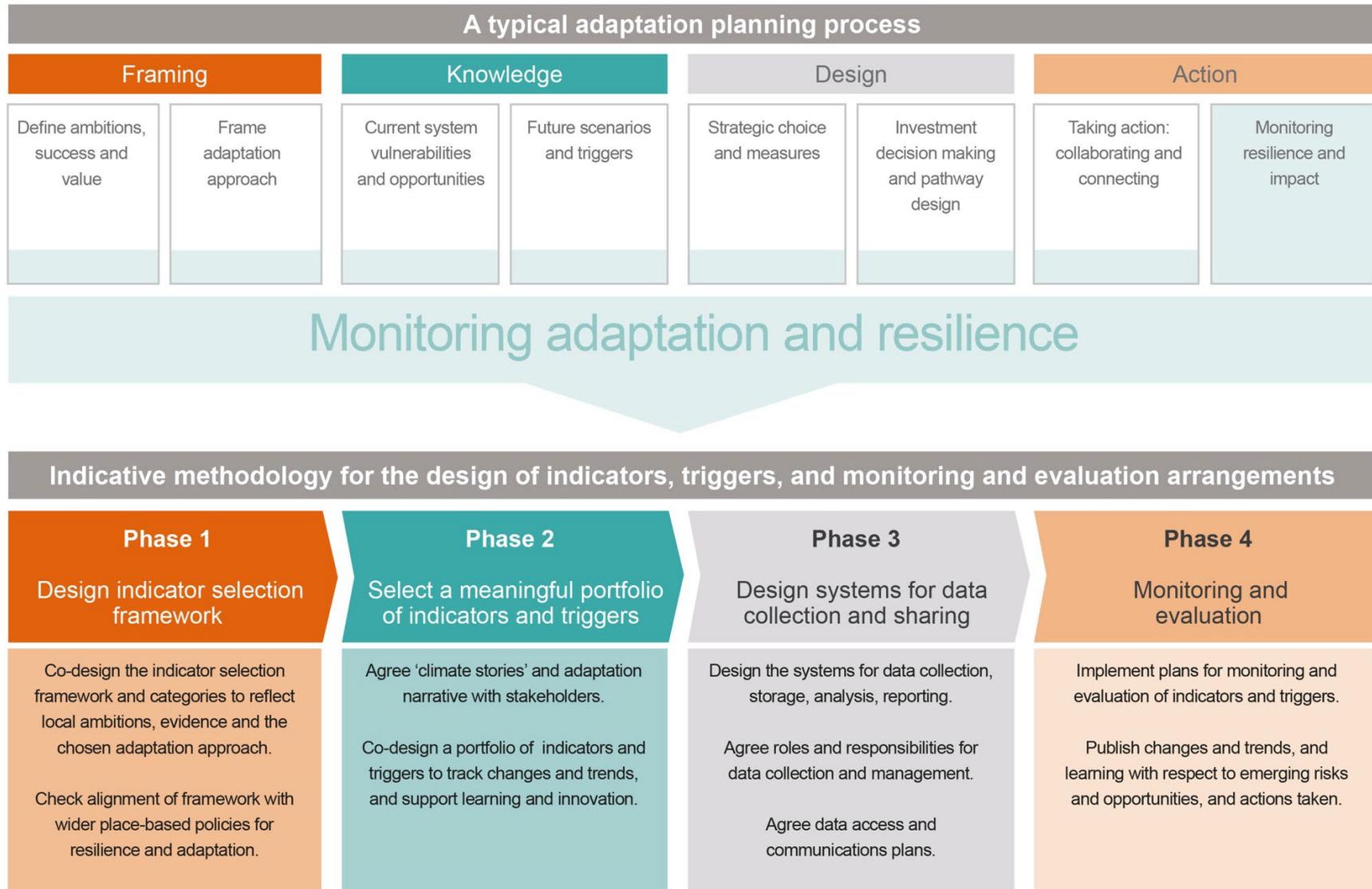


Figure 4: Indicative process for developing a monitoring and evaluation framework for adaptation



## 7 Recommendations for guidance

To support Local Authorities in making a shift to **a managed adaptive approach to flood risk management planning** it is recommended, based on this research, that the future SEPA guidance addresses the 12 aspects set-out in *Table 9*.

Table 9: Recommended aspects to be addressed in guidance

#	Key aspect
1	<p><b>Flood resilience and climate adaptation</b></p> <p>Frame the guidance in terms of <i>flood resilience and climate adaptation</i> to align the planning approach with wider place-based policies, emerging climate mitigation and adaptation best practices, and an outcomes-based approach.</p>
2	<p><b>Learning and innovation</b></p> <p>Design the guidance to support capacity building through learning by doing; and support innovation and the development of new ways of working through pilots, experimentation, and the sharing of lessons.</p>
3	<p><b>Working definitions and principles</b></p> <p>Provide working definitions and a set of adaptation principles to provide a common understanding of language, terms and practices; and support multi-disciplinary team collaboration and cross-sectoral decision making.</p>
4	<p><b>Framing and local ambitions</b></p> <p>Frame managed adaptive approaches flexibly within the guidance, so the concept can continue to support asset-orientated, stakeholder-orientated and transformation-orientated approaches, and support the place sensitive nature of adaptation ambitions and outcomes, and local choices.</p>
5	<p><b>Outcomes-based planning</b></p> <p>To support the shift to outcomes-based planning and decision-making, and the consideration of both current and future generations, that is inherent within managed adaptive approaches, it will be beneficial to embed Theory of Change practice (or similar practices) within the guidance. This will support the understanding of and co-design of outcomes, the identification of decision points and triggers, and subsequent monitoring, evaluation and learning. Relevant sources include: HM Treasury Guidance “The Magenta Book”<sup>25</sup>.</p>
6	<p><b>Co-design, collaboration and engagement</b></p> <p>Recognising the successful use of managed adaptive approaches is not only technical, but also a creative and social process, it will be beneficial to sign-post advice on co-design, collaboration and engagement within the guidance. Relevant sources include: Design Council ‘Beyond Net Zero – A Systemic Design Approach’<sup>26</sup> and Architecture and Design Scotland “Designing for a Changing Climate”<sup>27</sup> and “The Place Standard Tool”<sup>28</sup>.</p>
	<b>Designing for uncertainty</b>

<sup>25</sup> <https://www.gov.uk/government/publications/the-magenta-book>

<sup>26</sup> <https://www.designcouncil.org.uk/resources/guide/beyond-net-zero-systemic-design-approach>

<sup>27</sup> <https://www.ads.org.uk/wp-content/uploads/Carbon-Conscious-Places-Main-Report.pdf>

<sup>28</sup> <https://www.ads.org.uk/placestandard/>

7	Recognising that designing for uncertainty is a new skillset that differs from traditional planning practice, it will be beneficial for the guidance to sign-post emerging best practices such as the British Standards: ISO 14092:2020 “Adaptation to climate change – Requirements and guidance on adaptation planning for local governments and communities” <sup>29</sup> .
8	<p><b>Data and evidence</b></p> <p>To best support managed adaptive approaches, and the practice of designing for uncertainty, the guidance will need to support Local Authorities and partners in accessing, collating and making best use of three types of evidence:</p> <ul style="list-style-type: none"> <li>○ existing climate and scientific evidence;</li> <li>○ existing local knowledge, insights and ‘lived experience’; and</li> <li>○ new evidence that can be created by taking and evaluating action.</li> </ul> <p>For managed adaptive approaches to be cost effective, timely and meaningful to stakeholders, the guidance should encourage decision makers to place equal importance to the three types of evidence.</p>
9	<p><b>Decision points and triggers</b></p> <p>It will be valuable for the guidance to describe design principles and characteristics for decision points and triggers. To support a focus on resilience and outcomes, it will be important the guidance recognises that triggers can reflect a wide range of changing social, economic and environmental conditions (risks and/or opportunities); and due to the place-sensitive nature of adaptation choices, need to be meaningful to decision makers at the local level.</p>
10	<p><b>Grey, Green and Soft measures</b></p> <p>A central aspect of a managed adaptive approach is enhancing local resilience to flooding through best use of a combination of grey, green and soft measures. To support awareness and confidence in the range of measures that are available it will be beneficial to showcase examples within the guidance.</p>
11	<p><b>Business case development</b></p> <p>To support implementation, and funding and finance, of measures arising from a managed adaptive approach to planning, it will be important for the guidance to signpost emerging practices related to the economic appraisal of mitigation and adaptation investments; and potential sources of funding and finance. It will also be beneficial to local authorities to provide guidance on procuring outcomes; and adaptation governance.</p>
12	<p><b>Monitoring and evaluation</b></p> <p>Finally, as monitoring and evaluation is intrinsic to taking a managed adaptive approach it is important the guidance set-outs principles for indicator design and measurement. The six principles described in the recent CXC publication “<i>A monitoring and evaluation framework for the second SCAAP</i>” (2019)<sup>30</sup> provides a useful starting point for this.</p>

<sup>29</sup> <https://shop.bsigroup.com/products/adaptation-to-climate-change-requirements-and-guidance-on-adaptation-planning-for-local-governments-and-communities/standard>

<sup>30</sup> <https://www.climateexchange.org.uk/media/3913/cxc-a-monitoring-and-evaluation-framework-for-the-second-sccap.pdf>

Furthermore, this research and previous relevant ClimateXChange research<sup>31</sup>, highlights the importance of the ‘*getting started and framing*’ phase and involvement of stakeholders at this initial stage. To set adaptation investments up for success, it is therefore recommended (regardless of the approach adopted) that step 1 of the process is positioned as a readiness assessment and includes the activities set-out in *Table 10*. This approach complements the British Standard (BS 8631:2021) but places more emphasis on the framing of investment ambitions and the importance of co-design of the aims and process with stakeholders.

Table 10: Recommended Step 1 in adaptation process (Readiness Assessment)

Core activities	Description
Define ambitions, success and values	<p>Ambitions should be co-designed with stakeholders and include a local definition of resilience (now and in the future).</p> <p>Key deliverables:</p> <ul style="list-style-type: none"> <li>• Statement of adaptation ambitions and a definition of resilience (building on local place-based plans/strategies)</li> <li>• Summary of success criteria and design principles</li> </ul>
Plan the adaptation process	<p>Co-design of the process and approach with stakeholders.</p> <p>Key deliverables:</p> <ul style="list-style-type: none"> <li>• Project Plan/Routemap (agreed process and strategy)</li> <li>• Governance arrangements</li> <li>• Communications and engagement strategy</li> <li>• Spatial boundary for the investment</li> <li>• Long-term planning horizon (years)</li> </ul>
Funding and finance	<p>Initial assessment of the potential funding and financing opportunities reflecting the adaptation ambitions and wider local, regional and national strategies, policies and plans.</p> <p>Key deliverable:</p> <ul style="list-style-type: none"> <li>• Funding and financing strategy (short-term, medium-term and long-term) including an outline of the approach to business case and benefits realisation.</li> </ul>
Monitoring and evaluation	<p>Drawing on the statement of ambitions and definition of resilience an initial assessment of indicators needs and data availability should be completed.</p> <p>Key deliverables:</p> <ul style="list-style-type: none"> <li>• Initial assessment of indicators needs and an outline monitoring and evaluation strategy</li> <li>• Initial assessment of data availability and evidence gaps (Type 1, 2 and 3 below) and approach to data management.</li> </ul> <ol style="list-style-type: none"> <li>1. existing climate and scientific evidence</li> <li>2. existing local knowledge, insights and ‘lived experience’</li> <li>3. new evidence that can be created by taking and evaluating adaptation actions</li> </ol>
Capacity building and learning	<p>An initial assessment of the capacity and capabilities of the project partners should be undertaken to determine resource, expertise and skills needs. This assessment should consider the importance of</p>

<sup>31</sup> <https://www.climatexchange.org.uk/media/4669/cxc-international-practice-on-assessing-investment-needs-and-securing-investment-to-adapt-march-2021.pdf>

Core activities	Description
	fulfilling four key design roles: systems thinker, leader and storyteller, designer and maker, and connector and convenor.  Key deliverable: <ul style="list-style-type: none"> <li>• Plan for building capacity and learning</li> </ul>

Guidance will be valuable to Local Authorities and partners in making a shift to a managed adaptive approach. However, guidance alone will not be sufficient to bridge policy ambitions with operational practice; and foster learning between strategy and implementation. To achieve this, it will be important to incentivise and reward Local Authorities for leading the way and building capacity through learning by doing.

Recognising that a shift to managed adaptive practices will be a journey, it is a further recommendation of this research that future guidance is supported by development of a route-map for: operationalising managed adaptive approaches (through pilot projects and applied research), overcoming potential obstacles, and learning from implementation and successes.

## 8 Conclusions

Although guidance is recognised as important to embedding a managed adaptive approach to flood risk management, it is also clear that guidance by itself will not be sufficient to rapidly scale practice and that funding and resources will be necessary if managed adaptive practices are to be adopted at scale, and have an impact within the life-time of the six year flood risk management investment cycle (2022-2027).

This research demonstrates that managed adaptive approaches to flood risk management in Scotland are far from mainstream; and the limited number of suitable case studies is evidence that emerging practice is not yet keeping pace with policy ambitions for a more forward-looking approach that recognises future climate uncertainties within decision making and investment practices.

The three case studies explored in this research, illustrate the concept of a managed adaptive approach although not widely in use, is flexible enough to support a range of local circumstances and applications, including: asset-orientated, stakeholder-orientated and transformation-orientated adaptation ambitions and investments. All participants interviewed for this research expressed value in the practice, and in the learning and insights gained from making use of and piloting the approach; and each case study team is looking to make further use of a managed adaptive approach to support future collaboration, and help establish a clear narrative for future actions and investment.

Challenges were identified to the hosting of data and evidence, and making data accessible and meaningful to all stakeholders. However, data availability itself was not seen as a primary barrier to taking a managed adaptive approach. Some tension was expressed as to 'what constitutes evidence' and that more value should be placed on local knowledge and insights, alongside climate and scientific evidence. The importance of 'learning by doing' was also recognised as inherent to the approach and an important part of creating future evidence and understanding emerging risks and opportunities.

More of a challenge to the teams than data, was the expressed availability of expertise, and practical guidance, related to managed adaptive approaches in flood risk management; and the practice of designing for uncertainty which was recognised as a new mindset and an important new technical skill. For each case study, significant goodwill has gone into the piloting of a managed adaptive approach, and looking forward the projects are all looking to identify additional upfront funding and dedicated resources.

There was a strong desire from participants for guidance to establish a shared understanding of the approach and sign-post existing best practice and methods. The diversity of the three case studies does however demonstrate that some caution needs to be adopted in developing guidance and methodologies that are too standardised.

Standardisation could undermine, or unnecessarily restrict, the value of the approach, and become a barrier to innovation, experimentation and learning which are inherent to the approach.

At this time, none of the case studies have explored the design of triggers, and the associated adaptation choices and monitoring and evaluation frameworks, in detail. However, all the participants recognised the importance of establishing triggers that are meaningful to stakeholders and decision-makers, and cover not just climate triggers but also wider socio-economic and environmental triggers, and future opportunities. The project teams do not have experience of this and are looking for support and guidance regarding trigger design and establishing monitoring and evaluation frameworks.

The application of a managed adaptive approach to flood risk management planning, the design of triggers and indicators for measuring resilience and adaptation progress, and the use of monitoring and evaluation for adaptation are related and emerging areas of practice. It is valuable to recognise that the three case studies have not found the emerging nature of the practice an unsurmountable barrier to making progress. The case studies demonstrate the value of “learning by doing” which in itself is a core aspect of taking a managed adaptive approach to flood risk management planning, and important to scaling up future activity and promoting successes.

## References

The following 10 publications were reviews as part of the literature review:

- Allison, R., Haasnoot, M., Reeder, T., Green, M. 2021. Literature review on an adaptive approach to flood and coastal risk management. Environment Agency, FRS19221
- Bloeman, P., Reeder, T., Zevenbergen, C., Rijke, J., Kingsborough, A. 2018. Lessons learned from applying adaptation pathways in flood risk management and challenges for the further development of this approach. *Mitigation and adaptation strategies for global change*, 23, 1083-1108
- Bosomworth, K., Harwood, A., Leith, P., and Wallis, P. (2015) *Adaptation Pathways: a playbook for developing options for climate change adaptation in Natural Resource Management*. Southern Slopes Climate Change Adaptation Research Partnership (SCARP): RMIT University, University of Tasmania, and Monash University
- Climate change adaptation planning guidance - for ports and inland waterways. 2020. PIANC. EnviCom WG Report no. 178
- CoastAdapt, 2017. Pathways approach to adaptation. Government of Australia. Webpage accessed at: <https://coastadapt.com.au/pathways-approach>
- Coulter, L. (2019). User Guide for the Climate Change Adaptation Pathways Framework: Supporting Sustainable Local Food in B.C. Prepared for the B.C. Ministry of Agriculture through the 2018-19 Mitacs Science Policy Fellowship. Victoria, B.C.
- Haasnoot M., Warren A., Kwakkel J.H. (2019) Dynamic Adaptive Policy Pathways (DAPP). In: Marchau V., Walker W., Bloemen P., Popper S. (eds) *Decision Making under Deep Uncertainty*. Springer, Cham. [https://doi.org/10.1007/978-3-030-05252-2\\_4](https://doi.org/10.1007/978-3-030-05252-2_4)
- Hiller, A., Westcott, M., Walker, O., Hartman, M., Kolen, B., Ratering Arntz, L. 2019. Taking a managed adaptive approach to flood risk management planning in Scotland. *ClimateXChange*
- Stephens, S.A., Bell, R.G., Lawrence, J. 2018. Developing signals to trigger adaptation to sea-level rise. *Environmental Research Letters*, 13, 104004
- Werners, S.E., Wise, R. M., Butler, J.R.A., Totin, E., Vincent, K. 2021. Adaptation Pathways: A review of approaches and a learning framework. *Environmental Science and Policy* 116, 266-275

## Appendix A Interview topic guides

### Topic Guide for first interview (introductory meeting)

Ref	Key questions	Prompts
<b>Introduction</b>		
-	Introduce yourself and thank interviewee for their time. Note that the interview is estimated to take 50-55 minutes and check that they are ok for time.	
-	Introduce the research.	
-	Recording: Are you happy for me to record this call (for accurate write-up and to allow the extraction of verbatim quotes)? Recordings will be stored securely and destroyed within 6 months of the completion of the project.	
-	<p>Purpose of interview:</p> <p>The purpose of this meeting is to understand more about &lt;project name&gt;, how you are approaching taking an adaptive approach, your ambitions and where you are on this journey. We have identified &lt;project name&gt; as the project of interest where you are taking an adaptive approach – is this what you are expecting?</p> <p>Are there any other adaptive projects you would also like to discuss today or think is relevant to this conversation?</p>	
-	Do you have any questions before we proceed?	
<b>Overview and context</b>		
<b>Background and project status</b>		
1	Tell me about <project name> – please can you give me an overview of the project?	
2	What is the status of <project name> now?	<p>What stage is it in now?</p> <p>How long has it been running?</p> <p>Timeframes of delivery?</p>
3	How was the project initiated?	<p>Who initiated the project?</p> <p>Why now?</p>
4	What does adaptive approaches mean to you and the project?	<p>How do you understand the term adaptive approaches?</p> <p>What do you understand an adaptive approach involves?</p>
5	Where are you on the journey to developing adaptive approach for <project name>?	<p>If useful:</p> <ul style="list-style-type: none"> <li>• Understanding what it is</li> <li>• Finding out how to do it</li> <li>• Doing/know how do it</li> <li>• Have options &amp; deciding</li> </ul>
6	In what way is <project name> taking an adaptive approach?	<p>Why has this approach been chosen?</p> <p>Who was involved in the decision-making?</p>
7	What do you think should be included within an adaptive plan?	
<b>Framing of objectives and ambitions</b>		
8	What are the ambitions and objectives of <project name>?	What are you aiming to achieve from this approach?

Ref	Key questions	Prompts
		Get signposted to relevant reports/plans that document these Explore for each project if multiple
9	What are the drivers for taking an adaptive approach?	Why is this approach being taken? – political / social/ economic / cultural etc
10	What is the end goal and product(s)	What is desired outcome? What is the product? (plans, agreements, route-map, money, delivery)
<b>Place-making and co-benefits</b>		
11	How are you using adaptive approaches to deliver on wider place-making?	How does the project tie in with other initiatives/ strategies/ regeneration plans etc? How is it being integrated with other plans?
12	What other benefits are you seeking to deliver through this adaptive approach?	For example: social – community – economic – political – environmental benefits.
<b>Participation and engagement</b>		
13	How are you working with partners to deliver <project name>?	Which partners are involved? How are they involved? How did you get them onboard and engaged?
14	How do you see the role of engagement in understanding local thresholds and contexts to inform your adaptive approach?	
15	How much interest is there publicly and politically in this work?	How are you managing these communications?
16	What wider public engagement is being undertaken as part of this project?	
<b>Evidence and other interviewees</b>		
17	What plans/strategies/documents do you have on the areas we have discussed that you could share with us to understand more detail and wider connections?	Specifically: Project vision and objectives / adaptive plan or strategy / other place-making documents / wider related initiatives/ committee papers etc documenting position Work to identify relevant documents with them and ask to send them over to be included in the review
18	Which other colleagues or partners would it be useful to talk with at a later date who are involved in this project?	What is their role/org? And what would be their particular area of understanding / responsibility to add?
19	In the next interview we would like to discuss in more detail your thoughts on triggers and thresholds, monitoring and evaluation, adaptation measures and lessons learnt.	Aim to set a date for next interview
20	Is there anything else you would like to add at this point that we haven't covered yet?	

**Topic Guide for second interviews (main meeting)**

Ref	Key questions	Prompts
<b>Introductions</b>		
-	Introduce yourself and thank interviewee for their time. Note that the interview is estimated to take 50-55 minutes and check that they are ok for time.	
-	Introduce the research.	
	Purpose of interview: Areas of discussion and confirm the project to be discussed.	
-	Recording: Are you happy for me to record this call (to ensure an accurate write-up and allow the extraction of verbatim quotes)? Recordings will be stored securely and destroyed within 6 months of the completion of the project.	
-	Check if they have any questions before you proceed.	
<b>Overview</b>		
	Interviewer: <Summarise the project you will be talking about – what discussed in the last meeting – today discussing data and skills to deliver adaptive plans with a focus on trigger points and adaptive measures.>	
<b>2A: What extent is the relevant data and evidence available and/or accessible in developing plan options?</b>		
<b>Adaptation measures and actions</b>		
0	Interviewer: <Review the adaptive approach that was discussed in the last meeting and check understanding>	
1a	How are you planning your approach to <u>developing the adaptive plan</u> ?	How did you decide this approach? How was this informed? Who was involved? What stage are you at?
1b	What is the approach you are taking to developing <u>adaptive measures</u> and options?	
2	What types of adaptive options are you considering?	How are you identifying these options? i.e. what is the process Is the approach driven by the data available or data being identified for the approach?
3	How are you (envisaging) assessing the adaptive options?	What considerations would go into the choice of adaptive measures you use? How did you decide to take this approach?
4	What data/evidence have you used or identified is needed to develop adaptive options?	The process being undertaken to identify
5	How available and accessible is this data?	Any specific access requirements? Who owns the data? Any data sharing processes? Other barriers to access?

Ref	Key questions	Prompts
6	What other data or evidence do you need that has not been accessible or available to you?	For what reasons? What are the barriers? What have you done (if anything) to overcome these gaps/barriers?
2B: What extent is the relevant skills and expertise available and/or accessible in developing plan options?		
Adaptation measures and actions		
7	Do you currently have the skills and expertise available to you to plan adaptation measures (as discussed above)?	If not, why not? What are the gaps? What are the barriers?
8	Have you done anything to fill these gaps in skills and expertise?	Training/development? Using consultants? Working with partners? etc
1A: What data and evidence is required in order to identify trigger points within adaptive flood risk management plans?		
Design of triggers and thresholds		
9	How familiar are you with the terminology of triggers and thresholds for adaptive planning?	What is your understanding? And how have you developed this understanding?
10	How are you approaching the design of triggers and thresholds in your adaptive planning?	How did you decide to take this approach?
11	How are you capturing the design of triggers and thresholds in your planning?	
12	How have you gone/or plan to go about identifying triggers and threshold points in the adaption plan?	Where getting the information/advice from? How will you make these decisions? Who will be involved?
13	How have you identified the data and evidence that you need for this task?	Process – and who else is involved? Where find out from?
14	What data and evidence do you need to undertake this?	What have you used? What data do you already have? Where are the gaps? How are you filling the gaps?
Monitoring and evaluation		
15	How familiar are you with the idea of monitoring and evaluation of triggers and thresholds to know when decisions need to be made in the adaptive plan?	Discuss understanding. Gaps in understanding
16	How have you found out/developed your understanding about monitoring triggers and thresholds?	What resources/reference info – or people/consultants etc?
17	(if relevant) - Tell me about how you are approaching designing a monitoring process for trigger points?	What indicators will be used? What process is undertaken to monitor them? If not currently being undertaken, how do you plan to/envisage this being undertaken? – Or what are you uncertain about?

Ref	Key questions	Prompts
18	Is the choice of adaptation actions that you may use for the adaptive plan influenced by your perception of how easy or difficult it is to monitor the associated trigger points?	
19	What data do you envisage using to monitor these indicators?	Is it currently available/accessible? Explore any data sharing/accessibility barriers.
20	What data is missing that is preventing you from monitoring/measuring these indicators?	Where are the gaps? What are you doing or could do to fill the gaps?
<b>1B: What skills and expertise is required in order to identify trigger points within adaptive flood risk management plans?</b>		
<b>Design of triggers and thresholds / monitoring and evaluation</b>		
21	Having discussed the need for identifying trigger points and monitoring indicators - what specialist skills or expertise do you envisage is needed to identify triggers and thresholds?	Types of skill sets/job roles – or external expertise – partner input - required
22	Do you have these skills available to you already? If not, how would you go about securing these skills/expertise?	Inside and outside the organisation including partners and consultants
<b>3A: How might data gaps be filled?</b>		
<b>3B: How might skills and expertise gaps be filled?</b>		
<b>Opportunities and lesson learnt</b>		
23	What do you think is needed to overcome the gaps in data availability and accessibility?	Pick up on specific gaps and barriers identified above What thoughts and ideas do you have on filling these gaps?
24	What do you think is needed to overcome the gaps in skills and expertise?	Pick up on specific gaps and barriers identified above What thoughts and ideas do you have on filling these gaps?
25	Is there anything else you are already doing to fill these gaps and overcome these barriers?	
<b>Closing</b>		
26	Are there any other lessons you have learnt that could be shared to help others through this process?	
27	Is there anything we have not covered that you would like to add on this topic?	
28	Request for evidence: Are there any other relevant documents/reports/plans/strategies that you could share related to the areas we have discussed today to provide some more context or detail?	

## Appendix B Outer Hebrides coastal adaptation

### B1 Background and framing of ambitions

In April 2019 a Climate Emergency was declared by the Scottish Government. At that time school protests and campaigns such as “Fridays for Future” were also taking place across Scotland. These protests were supported by children in the Outer Hebrides fostering a call to declare a climate emergency at the local level.

Working with the established Outer Hebrides Climate Planning Partnership (OHCPP)<sup>32</sup>, it was agreed that instead of declaring a Climate Emergency without a clear action plan, a Climate Change Working Group would be formed (September 2019) to develop a clear route-map, plans and targets for climate adaptation at the local level.

Rather than create targets in isolation from other strategies and plans, the ambition of the Working Group is to embed actions (both mitigation and adaptation) within an update of the Local Outcomes Improvement Plans (LOIP).

The LOIP is a statutory requirement of the Community Empowerment (Scotland) Act 2015, and the current 2017-2027 LOIP<sup>33</sup> for the Outer Hebrides has three main priorities over the next 10-20 years:

1. The Outer Hebrides retains and attracts people to ensure a sustainable population;
2. The Outer Hebrides has sustainable economic growth and all our people have access to appropriate employment opportunities; and
3. The islands offer attractive opportunities that improves the quality of life, wellbeing and health for all our people.

The current LOIP does not explicitly take account of climate change mitigation or the need for adaptation.

The Climate Change Working Group is largely formed of public organisations including the Statutory partners: the local authority, the Health Board, Police Scotland, the Scottish Fire and Rescue Service, and the Regional Transport. Furthermore, the Group includes civil society, third sector and academia, including: Community Land Scotland, Third Sector WI, Hebridean Housing Partnership, and UoHI. The initial set-up also included two members of the Scottish Youth Parliament, and collaboration with creative partners through the Lan Thide (the Outer Hebrides Climate Beacon). The set-up of the Working Group is shown in *Figure B1*.

Figure B1: Outer Hebrides Climate Planning Partnership – Climate Change Working Group



<sup>32</sup> <https://www.cne-siar.gov.uk/your-council/community-planning/>

<sup>33</sup> [http://www.ohcpp.org.uk/images/OH\\_CPP\\_Local\\_Outcomes\\_Improvement\\_Plan\\_2017-27.pdf](http://www.ohcpp.org.uk/images/OH_CPP_Local_Outcomes_Improvement_Plan_2017-27.pdf)

A project plan was designed by the Working Group with support from Adaptation Scotland to take a multi-hazard approach. The flexible plan had three Phases.

Phase 1: Background information and evidence gathering. This phase set-out to answer key local questions, such as:

- what is climate change and what does it mean to local partners and the community?
- what are the impacts (past and future) and how does this affect the elements valued on the islands?
- what does it mean to the provision of current and future services?
- what are the issues, and what may have to change?

Phase 1 included collating spatial datasets and mapping, climate impact interviews with CPP partners, community discussions and inputs as part of pilot engagement work in North Uist; and identification of climate hazards, and analysis of climate trends and projections; to determine and agree future priorities.

At the outset, Phases 2 and 3 were then anticipated to include a full Climate Change Risk Assessment, followed by development of specific climate adaptation actions to be embedded in the LOIP.

Currently the Working Group are concluding Phase 1 and looking to prioritise and agree the next steps, including resource and funding commitments.

## **B2 Design of triggers and adaptation measures**

At this stage, the Working Group have not started the process of designing triggers and adaptation measures. However, core aspects of their approach, founded on the Phase 1 work, include:

- taking a multi-hazard approach to the assessment of triggers;
- listening to everyone to understand the '*lived experience*' of the local communities throughout the Outer Hebrides;
- exploring risks, impacts and opportunities at a scale that is meaningful to people and the place;
- designing triggers based on socio-economic-environmental and climate thresholds and an understanding of what communities value and what they want to hold on to;
- embracing both 'risk-based' (climate risks) and 'positive future vision' (local ambitions) perspectives to frame and prioritise future adaptation actions; and
- developing climate stories to support adaptation actions.

To date, 29 short-term and 18 long-term climate risks and opportunities have been identified across the four categories below:

1. Natural and historic environment
2. Built environment
3. Society and human health (and well-being)
4. Economy, business and industry

The short-term flood related impacts are categorised in *Table B1*, and the additional long-term flood (and coastal change) related impacts are described in *Table B2*.

The Working Groups next step (Phase 2) is to explore the impacts and scenarios to establish a shared understanding of short, medium and long-term implications of climate change and the implications of different elements of risk.

Table B1: Short-term flood related impacts

Natural and historic environment	Built environment	Society and human health	Economy, business and industry
Increased flooding	Drainage system overflow	Decreased access to and delivery of services	Income uncertainty and increased costs to business
Increased landslides	Damage to housing	Destabilised food security	Construction delays
Decreased agricultural productivity	Road damage and closures	Increased social isolation	Decrease in tourism
Spread of invasive species	Disruption to piers, harbours and ports	Disruption to community events	Decrease in economic productivity
Biodiversity and habitat loss	Causeway and bridge closures and damage	-	-
Damage to peatlands	Damage to active travel	-	-
Damage to historic and heritage sites	Increased ferry and airport closures	-	-
-	Damage to energy infrastructure	-	-
-	Disruption to internet connectivity	-	-

Table B2: Additional long-term flood (and coastal change) related impacts

Natural and historic environment	Built environment	Society and human health	Economy, business and industry
Coastal erosion and retreat	Drainage system failure	Migration and population loss	Abandonment of commercial premises and assets
Biodiversity change and loss	Increased pressure on low-level property	-	-
Habitat change and loss	Pier, harbour and port abandonment	-	-
Loss of historic heritage sites and practices	Road network redundancy and relocation	-	-
-	Sewage system complications	-	-

### B3 Opportunities and lessons

The project team have described the status of the project as *'the end of the beginning'*, and are currently reflecting on what has been achieved and what needs to happen next to sustain and build momentum.

This section sets-out key insights and lessons arising from the work of the OHCPP Climate Change Working Group that may be valuable to informing adaptive management practices in other coastal areas and island regions.

#### Framing of objectives and ambitions

- Adopting a multi-hazard approach was valuable due to the local interdependencies between the various climate hazards and wider socio-economic-environmental impacts and risks. It was also recognised that the local communities only have a certain capacity to engage and that exploring all hazards together would avoid engagement fatigue and provide a stronger perspective of the ‘lived experience’ of residents.
- An important finding of the team was not to treat the Outer Hebrides as a single place. Across the 70 islands there is a significant amount of diversity (social, cultural, physical, environmental, and heritage) and it is important this is reflected in capacity, vulnerability assessment and impacts analysis. This diversity was also acknowledged by the Met Office partners who demonstrated that the same regional weather patterns across the Outer Hebrides do not result in the same weather conditions (such as wind speeds and rainfall) at the local level.
- Engagement demonstrated that it was important to frame the exercise in terms of current and future risks, and positive current and future aspirations/ ambitions to avoid being alarmist and to fully engage participants in climate conversations.
- Framing of the work in terms of developing actions to embed in the Local Outcomes Improvement Plan, provided a means for the Community Planning Partnership to drive this initial stage of work and leverage the goodwill of partners. As such the ambition of the partnership is not to create a new adaptation strategy and duplicate other partners activities, rather to embed climate adaptation within existing and future investment strategies and plans.

#### Place-making and co-benefits

- A key learning from the project team, is that for coastal and island communities the socio-economic and natural/environment are interdependent issues and should not be considered in isolation from each other in the hazard risk assessment. For the Outer Hebrides socio-economic factors such as sustainable economy, sustainable population and health and well-being are significant issues; and the marine environment and local natural capital and heritage play a critical role in defining the culture and resilience of the islands.

#### Participation and engagement

- The project team recognises that climate conversations are ‘sensitive conversations’ that need to be skilfully managed to avoid being alarmist. Tools such as the Place Standard Tool (and the associated Climate Lens<sup>34</sup>) are recognised as valuable approaches to engagement, but needing to be tailored to local circumstances to avoid being too procedural.
- The related Climate Beacons for COP26<sup>35</sup> initiative undertaken in the Outer Hebrides<sup>36</sup> was recognised as a valuable approach to engagement; unlocking wider insights at a geographical scale that was meaningful to people. The initiative also added capacity, created strong local networks and out reach across the islands, and brought creative partners into the broader governance and cooperation strategy for climate action, and establish new creative ways of engaging with communities.
- The project team have indicated that in the Outer Hebrides there is a good existing level of community resilience and adaptive capacity, including strong social networks and sense of place. This provides a good coping capacity for the community to respond to current shocks and stresses. The project team note that this existing coping capacity may in itself become a barrier to forward planning for changes in climate in the future, when there is a need or desire to move the community response from incremental changes to more transformational actions.

<sup>34</sup> <https://sustainablescotlandnetwork.org/news/place-standard-tool-pilot>

<sup>35</sup> <https://www.creativecarbonscotland.com/project/climate-beacons-for-cop26/#Hebrides>

<sup>36</sup> <https://lanthide.org>

### Scenarios

- The Outer Hebrides work has shown the value of Climate Impact Interviews, together with community dialogue and participatory mapping, to bring to life the *'lived experience'* of residents and communities. This evidence base is seen as essential in the Outer Hebrides to complementing and scientific data and establishing a shared view of *'what to hold on to'*. The team see this as an important first step in establishing triggers and future thresholds that are meaningful to local people and decision makers.
- The team also recognised the importance of validating scientific and spatial information through field work and site visits with communities (in their places) to fully understand the relationships between risks, vulnerability and opportunities; and that digital intelligence is not a substitute for professional and local insights on the ground.

### Data and evidence to design triggers and thresholds

- A lesson from the project team, is the importance of establishing a shared view of data needs and the definition of evidence; in terms of what is needed, to what level of detail, and when, in order to make commitments and design triggers and thresholds. Tension between professional perspectives, on data and evidence, is seen as a key future challenge to making timely investment decisions. The team recognise that making adaptive management decisions in the context of uncertainty is a new skill that the Working Group will need to embrace and develop as the project moves through the next project phase.

### Monitoring and evaluation

- Monitoring and evaluation has not been explored at this stage of the process, but the project team acknowledge that the resourcing of data management, hosting and analytics, and ensuring information accessibility to partners and the community will be key to this process going forward. Monitoring and evaluation is also a key aspect to Local Outcomes Improvement Plans.

### Opportunities and lessons learnt

- The project team stressed the importance of the FORMING process, insomuch that this was a new group, with a new way of working, with a new set of partners, and a new topic (adaptation). For the group to move ahead the team needed to go through some *'learning by doing together'* to inform the process and start planning and prioritising an approach that was right for the Outer Hebrides. Not setting a prescriptive terms of reference at the outset was considered important to ensuring the team had the flexibility to learn and build the necessary networks, partners and connections.
- To date the Working Group has made progress based on the goodwill, commitment and resources of the project partners. To take the next step it is recognised that additional financial commitment will be necessary and that dedicated resources will be important to move faster and meet the expectations of the local community.

## Appendix C Moray fluvial adaptation

### C1 Background and framing of ambitions

Moray Council has a long history of responding to fluvial flood risk and has invested over £170 million in flood alleviation schemes since 2014 estimating to prevent damages of £85 million to date. This includes the flood alleviation schemes of Rothes, Elgin and Forres. For example, the Rothes Flood Alleviation Scheme completed in 2011, cost £25 million and protects around 200 residential and 18 commercial properties, avoiding damages of around £6.5 million to a 1 in 100 year plus climate change event.

Due to the significant investment undertaken by Moray Council in delivering these flood alleviation schemes, it is important for them to understand how risk will change in the future as climate change projections increase to maintain the protection provided by the defences. The modelling for the schemes was undertaken around 15 years ago. Whilst significant freeboard was built into the design, FEH (Flood Estimation Handbook) climate change allowances have increased since then making it uncertain what level of protection will be maintained into the future under different climate change scenarios. Moray Council therefore aims to use an adaptive pathways approach for each of the locations benefiting from defences to help understand and respond to future uncertainty and identify trigger points for when intervention or action is required.

The current ambition for the adaptive pathways approach is to be able to maintain the original design standard provided by the existing defences with the uncertainty of climate change and understand the tipping points in the system to know when further intervention is required.

The approach being developed is equally considered a tool for long-term Council decision making and investment planning, and for effective communication with Elected Members and communities. One benefit of developing adaptation pathways is the creation of visual pathways that help to communicate and create a common understanding across stakeholders of the trajectory they are headed and an understanding of the future potential implications.

### C2 Design of triggers and adaptation measures

#### Approach to adaptation pathways planning

Moray Council is early on in the process of developing adaptation pathways and has developed a 6-step approach:

1. Discuss rationale
2. Identify future levels of risk
3. Review levels of risk and changes over time
4. Identify triggers
5. Develop list of options
6. Create a pathway of options over time

The intention is to develop the plan and options in-house due to the importance of long-term monitoring of triggers and thresholds and integration of the plan across the Council. Therefore, building knowledge and understanding of adaptation pathways by in-house officers will create ownership of the adaptive approach. This would be supported by outsourced technical specialists i.e. hydrologists and modellers, to develop the current and future understanding of risk to inform the plan development.

#### Understanding risk

The Council is currently undertaking further modelling with consultants to understand the current and future risk under climate change scenarios. This first step will identify what standard of protection is being provided now with updated climate change allowances and at what points in the future that standard of protection may be reduced to understand how

assets respond under changing scenarios. As fast response catchments with risk from extreme and high intensity events as well as risk from combined sources, there is a high level of uncertainty in modelling the system. Gaps in knowledge include surface water and fluvial interactions, how the geomorphology will respond to extreme events, and how water abstraction may change in the future and affect water levels. Whilst the systems are gauged, there is only 10 years of data which does not provide a long-term record for future predictions. This creates uncertainty in understanding future risk and predictions compared to, for example, a coastal system with long records and limited interacting sources.

### Adaptation measures

To develop adaptation options, a long list of adaptive measures have been developed that will be reviewed for viability for each location following finalisation of model outputs. A short list will then be collaboratively developed with stakeholders, affected communities and partners to develop adaptive pathways. Due to the uncertainty in the system described above, it is likely that continued monitoring to build the evidence base will be an early-stage action in the adaptation plan rather than implementation of adaptation measures in the short-term.

Table 4: Adaptation measures

<b>1. Monitoring</b>	<ul style="list-style-type: none"> <li>• Enhanced rainfall and river level monitoring</li> <li>• Analyse for trends (but only have 10 years of data)</li> </ul>
<b>2. Community</b>	<ul style="list-style-type: none"> <li>• Community engagement and awareness raising</li> <li>• Community resilience measures (e.g. flood action group, town plan)</li> <li>• Development and guidelines to improve resilience</li> </ul>
<b>3. Operational response</b>	<ul style="list-style-type: none"> <li>• Flood warning service</li> <li>• Target incident management (e.g. sand-bags, demountable defences)</li> </ul>
<b>4. Physical</b>	<ul style="list-style-type: none"> <li>• Physical measures such as raising defences, creating diversion channels, upstream storage, nature-based solutions</li> <li>• Changes in land-use management e.g. reforestation and farming</li> <li>• Increasing capacity of road crossings</li> <li>• Intelligent phasing e.g. development planning slowing down flow vs speed up flow depending on interactions</li> <li>• Property Level Protection</li> </ul>

### Design of triggers

Design and monitoring of triggers is seen as the most challenging step in developing adaptation pathways due to the range of interacting variables involved in a fluvial system. Adaptation pathways are reasonably established for coastal systems, with long records for sea level rise and coastal erosion allowing future forecasts, this is less established for fluvial systems which often have limited data available in comparison. Additionally, there are few examples of adaptation pathways developed for fluvial systems to provide a precedent to draw on.

Potential triggers and monitoring approaches have been considered that may be appropriate for the Rothes. The aim is to develop hydrological triggers that are easy and low-cost to monitor and provide insight into the systems thresholds. Whilst these have not been finalised, they indicate the type of indicators and considerations available for this type of system:

1. **Yearly rainfall averages:** Monitoring average yearly rainfall with a trigger point identified when the average exceeds a % over the long-term average.
2. **Frequency of high intensity events:** As intensity and duration of rainfall are likely more important as an indicator of risk on this type of catchment than rainfall averages, then the number of high intensity events above a certain threshold could be used to identify an upcoming tipping point.

3. **Annual river flows:** Median annual flow (Qmed) or maximum annual flow (Qmax) meeting a certain threshold point could be used as indicators to identify repeating high flow events.
4. **Freeboard allowance:** As additional freeboard has been built into the flood alleviation schemes to allow for uncertainty, monitoring how the additional freeboard has been reduced over time with updated modelling would provide an indication of when the standard of protection has reduced with the latest climate change allowances. A reduced level of threshold could correspond to a trigger point e.g. trigger point 1 when at 75% of freeboard, trigger point 2 when at 50% of freeboard etc. This would take a similar approach to coastal adaptation using sea level rise allowances for trigger points. As this indicator is dependent on regularly updating modelling when FEH advice changes, it does not track real-time changes in the system so risks being untimely.

Whilst the focus is on developing hydrological triggers, there is potential and interest to develop socio-economic triggers to feed into master planning. These triggers are likely to be more easily understood and embraced by political members which could help embed the adaptation pathways approach within the Council.

### C3 Opportunities and lessons

A number of opportunities from the experiences at Moray Council have been suggested to support the process of adaptive management for fluvial systems particularly with existing defences:

- as there is no single source of guidance available for adaptive management in Scotland, it would be useful to develop a national approach for developing triggers including ideas for types of triggers, the available data and how these can be suitably monitored;
- there is currently a lack of examples of applying adaptive management and adaptation pathways in areas that already have a scheme in place;
- creating a consistent approach to adaptive management and the design of adaptation pathways could assist procurement of consultants and setting briefs;
- there is value in having opportunities to have more conversations and co-creation with other local authorities about adaptive management to help develop and share ideas on developing managed adaptive approaches;
- there is a need for more education and awareness of what adaptive management is. This includes for practitioners to fully understand the process and concept and how to best deliver, as well as non-practitioners such as political members to understand the concept of planning under uncertainty. Often it can be perceived that it is decision-making avoidance and pushing difficult decisions into the future rather than long-term strategic investment planning; and
- as well as awareness raising, there is a need to develop consistent terminology within the field. Adaptation is used across multiple sectors to mean different things with different plans – even across departments within the Council (e.g. Climate Adaptation Plans vs Adaptation Pathways etc). A common terminology that bridges all adaptation planning areas could create a shared understanding of adaptive management and support collaboration.

## Appendix D Clyde tidal adaptation

### D1 Background and framing of ambitions

Glasgow and the Clyde region is at risk from increased flooding due to climate change from surface water, the rivers, and the sea. The area is also important to local, regional and

national economic growth and prosperity. As such, the Clyde Mission, and associated River Clyde Corridor, was identified as a National Development in the draft NPF4 to support the aims of the long term spatial plan for Scotland.

The Clyde Mission is a national, place-based economic development initiative that seeks to achieve a Grand Challenge: *“to make the Clyde an engine of sustainable and inclusive growth, for the city, the region and for Scotland”*. The Clyde Mission is a cross-sector collective of those with the knowledge, resource and levers to help achieve the Grand Challenge. It comprises five interlinked Missions, that seek to deliver benefits for the environment, businesses and communities. The five Missions are: create new, good and green jobs and a workforce with the skills to secure those jobs; use vacant and derelict land for the benefit of the economy, the environment and communities; adapt to climate risks, especially flooding (Adaptation Mission); Accelerate Scotland’s progress to net zero; and use the river to create better places for people and communities.

The Adaptation Mission initiated in summer 2021 was set up to facilitate planning for adaptation to climate risks (especially flooding) for the Clyde. The process is at an early stage of development. The insights and observations set-out in this case study are drawn from interviews with four of the Adaptation Mission contributors.

## **D2 Design of triggers and adaptation measures**

Experience from within the Adaptation Mission membership either from designing triggers and adaptation measures elsewhere, or from the local knowledge available in the team, has provided an insight into how the design of triggers and measures could be approached for the Clyde. Aspects of the approach being considered includes:

- Historically, hydrological tipping points have been used to identify the next set of interventions; this only represents part of the picture in the more complex adaptive systems where there are also economic, social and political drivers, which may be looking to consider what becomes an ‘acceptable’ tipping point, or a combination of tipping points that need to be reviewed cumulatively to identify the potential range of interventions.
- Accepting that site allocation for a given purpose may only be for the short to medium term and appreciating that this purpose may change at any point in that time frame, subject to emerging climate scenarios.
- Acknowledging that assets need replacing over time, and generating different scenarios that lead to a ‘no regrets’ approach.
- Agreeing the ‘acceptable level of risk’; who, what and how can these decisions be made and consideration of how this is communicated to those most severely impacted by the risk.
- Identifying the importance and complexity of the relationship in a tidal flood risk environment between updated flood risk model outputs, and the review of planning requirements in delivering adaptive planning approaches.
- Local development plans are being developed and this is an opportunity to bring adaptation planning to the forefront of planning developments. The increased profile from the declared climate emergency and this Mission work, is increasing the awareness and priority locally.

In addition, in considering the development of tipping points, triggers and adaptation measures, there is the key question of what does adaptation mean for Glasgow? The connectivity between the city and its water is critical to success in developing and delivering any scale of adaptation plan. Herewith an opportunity to live with water and firmly tie the role of the Clyde in with the city’s future resilience, and vice versa, enabling the prosperity of Glasgow as a thriving city, now and in the future, to support the sustainability of the Clyde as a multi-faceted asset.

### **D3 Opportunities and lessons**

The Clyde Adaptation Mission acknowledges the level of work, collaboration, engagement, and momentum to maintain the enthusiasm already brought to the table by its partners. This section on opportunities and lessons is brought together by a wealth of knowledge from members of the Mission, both in working in the Clyde Adaptation Mission, in living and working in the Clyde region, and in reflection of their personal experiences in the Clyde and beyond.

#### Data

Over the past two years, the fluvial model for the River Clyde has been reviewed and updated to be made appropriate for use in assessing risk in the fluvial environment. The tidal reach of the River Clyde is to be updated to complete the revisions to the Clyde model, and where possible, actions such as the digitisation of historical data will aid the development of the understanding of how the Clyde has changed over time.

As with all modelling, there is always more that can be done to create a more accurate, or a fuller picture of the risk. The Clyde faces the complex interaction of different types of flooding which is challenging from a hydrological perspective. Additional work with modelling would give the scientists more certainty, however, it is acknowledged that adaptation is about dealing with uncertainty rather than identifying and managing certainty. A key element of this modelling would be the overlaying of data so that there is a visual representation the tidal flood risk with the economic, social, physical influences for the Clyde. A clever way of communicating the plans, would enable constructive responses and support for the future delivery. This would assist in both decision-making and in communications of the bigger picture.

From a planning perspective, the local authorities in the Clyde Region have development plans that are due to be renewed. It is anticipated that these plans will feed into the adaptation planning. However, as all the authorities work to different timelines, and the staged release of data from authorities may mean the Mission misses out on some data release. Therefore, an approach to capturing data at a later opportunity will need to be identified.

The impact of the COVID-19 pandemic on future development planning is uncertain. There may be a possible change in favour of increased residential housing in areas previously earmarked for offices or other purposes. There would be a benefit of understanding what landowners intend to do with their land to understand if the landowner plans will fit with the adaptation plans; it is felt that an overview of this is currently missing. Further to this, and to be considered in the planning framework is clarity of population change, as well as associated land use change.

SEPA guidance on development on the functional floodplain has an impact on how development could be approached and reviewed in the planning environment for the future. Preview of future changes to SEPA's guidance would benefit any adaptation planning approaches and updates.

A final message to bring forward for discussion is the challenges associated with data from different sources being provided in varying formats, timescales, access, and availability. The benefit of data being consistent to ensure a compatible and regular review of critical factors that influence the actions the region delivers is important.

#### Skills and expertise

The ability to collaborate is a skill. The technical skills are available in the wider market, the enthusiasm is there, and the right collaborative approach will enable change. A limitation is capacity and space to deliver change. The current structure for place-making limits change as there is no space for wider interdisciplinary teams to work together. Given the right conditions and support, there would be increased opportunity. Collaboration is vital for system and systemic changes.

The creation of an independent organisation with a remit to make change happen, removes the fundamental need for collaboration between organisations and reduces the ability for collaboration to happen by creating additional boundaries to those that already exist. An approach such as adaptation in the Clyde takes place-based working; something that has not, to knowledge, been done at this scale before.

The components of the skills required to deliver the future adaptation plan exist. For example, there are flood risk experts, engineers, planners, communications officers, but dedicate time and money to expand the breadth and width of their application of their knowledge into the bigger picture. Finding the people who have this breadth of knowledge is key to the future delivery, enabling them to share wisdom and broaden the resources we have available to deliver adaptation.

Adaptation is a term that is becoming more familiar with the working population in the engineering, environmental and planning fields. However, there is uncertainty over how much knowledge resides in these areas with specific relation to adaptation, pathways and the understanding and application of tipping points and triggers. There is a feeling that as this initiative grows, people will be allocated roles for ‘adaptation’ without fully understanding the term. We learn through delivering, however, there is a risk that without the experience and understanding, terms may be misinterpreted, and actions misconstrued. An opportunity to mitigate this could be through having a defined list of interventions and a glossary for what specific terms mean for Glasgow and the Clyde so that new people responsible for adaptation delivery can use both as a guide for themselves and their respective organisations.

In identifying the gaps in skills and expertise, we also look to how we can strengthen this. Here our education system may be able to support if we start having discussions with the education sector now. Education on resilience and adaptation is starting to infiltrate our workplaces. Skills Development Scotland produced the Climate Emergency Skills Action Plan to help highlight training needs. We need to see skills development and education change to be able to implement adaptation across the country.

- How can we best utilise existing skills to work together to deliver climate resilience and deliver adaptation pathways?
- How can we professionalise approaches to bring them into existing practice and then capacity build?
- How can we introduce adaptation planning into learning in the higher education system across all degree level courses?
- How can we build on the well documented school curriculum on climate change to build awareness of climate resilience and adaptation?
- Will our political representatives deliver the key adaptation messages?

### Engagement and collaboration

Engagement is hugely important, and the role of the organisations going forward will be hugely important. The challenge lies with the systemic nature of the work. This Mission requires collaboration at a scale that has never been delivered before within the Glasgow region. Project partners have resource constraints and reducing funds. The organisations are not designed for mass systemic collaboration and the mechanisms are not in place to enable this level of collaboration to occur. A newer way of working needs to be developed for Glasgow and the Clyde, for all the partners to enable space and leadership to allow systemic change in engagement to occur. It is widely felt that only once collaboration and engagement within the partners is resolved, can then wider engagement with the public be meaningful and effective.

### Decision making and governance

Decision making is a challenge, unless there is alignment and agreement from all parties, it is very easy to destabilise an approach. A consistent record and review of decisions with buy in from the political system is preferred that is not hindered by a local election and change of governance.

The Clyde Mission and its Mission groups were set up in response to the climate emergency and the need to achieve targets. Each of the five Missions is linked to each other through adaptation and a systems approach and one cannot, realistically, be delivered without the other. However, they are siloed in their aims and ambitions and work is needed to bring these together for the common goal of increasing Glasgow and the Clyde's resilience to climate change.

Organisations are resource limited and those resources are, in many cases, stretched. In building a partnership such as the adaptation pathway for Glasgow and the Clyde, for the approach to be successful, a suite of representatives from partner organisations needs to be in available to have meaningful discussions. There is often overlap between roles and responsibilities, and it is unrealistic to expect more than one or two people to attend one meeting from a single organisation. There is a need to have a single point of contact with a large enough breadth of knowledge that they can represent all the views of their organisation. This person is often someone of higher responsibility and has limitations on their availability.

### Finance

It is widely considered that investment in flood risk management is in the interest of the public good and is challenging, in many cases, to attribute to individual organisations. As a result, the cost of flood risk management is, for the most part, covered by the public purse. However, adaptation pathways deliver more widely than just flood risk, and the potential for funding is about sharing the risk and sharing the reward. This opens potential for public-private finance requiring governance (policy framework), structure, investment opportunities (public-private partnerships, fiscal incentives), resourcing (upskilling, educating) and a workforce to be able to deliver.

### Key lesson

Based on the experience of the Clyde participants, the following aspects are seen as key to developing adaptation plans and the next steps on the Clyde:

- development of a common glossary of terms defining what adaptation and resilience mean in the local context;
- collation of baseline data to support adaptation pathways design and subsequent monitoring and evaluation of trends and changes;
- establishing a deliver group, or a manageable size, that includes senior local leaders that can provide direction on policy, strategy, and governance; and a group member with previous adaptation planning experience.

## Appendix E Theory of Change

“Theory of Change (ToC) is a methodology for planning, participation, adaptive management, and evaluation that is used in companies, philanthropy, not-for-profit, international develop, research and government sectors to promote social change. Theory of Change defines long term goals and then maps backward to identify necessary preconditions” (*Source: Wikipedia*) and describe how and why a desired change is expected to happen in a particular context. The methodology is commonly

used in international development to provide a clear line of sight between investment inputs, actions, outputs, outcomes and impacts, and to support monitoring and evaluation, change management and learning.

In the context of a managed adaptive approach, use of the Theory of Change has the potential to:

- support outcome-based planning by fostering an approach that starts with the end in mind (outcomes and impacts). This will help to link adaptation actions and responses with resilience outcomes and test whether “the right things are being done”;
- support business case development by strengthening the transparency of “case for change” and the associated investment narrative; and
- support the development of the necessary monitoring and evaluation framework (and associated indicators and triggers) which is essential to taking a managed adaptive approach.

Useful background on the use of Theory of Change can be found in “HM Treasury Magenta Book – Central Government guidance on evaluation (March 2020) Chapter 2.2.1”<sup>37</sup>. The recently published “Defra Theory of Change Toolkit – SD1421”<sup>38</sup> (January 2022) also provides comprehensive and practical guidance on the development of a ToC and associated logic model.

The unpublished Environment Agency literature review “Monitoring and Evaluation for Climate Change Adaptation” (Shah et al, 2022) also identifies the following sources of information relevant to monitoring and evaluation and use of Theory of Change:

- “Monitoring & evaluation for climate change adaptation and resilience: A synthesis of tools, frameworks and approaches”<sup>39</sup> Bours et al, 2014 ((2<sup>nd</sup> edition)
- “Making Adaptation Count”<sup>40</sup> World Resources Institute (2011) and the related publication “Adaptation made to measure – A guidebook to the design and results-based monitoring of climate change adaptation projects”<sup>41</sup> GIZ; and
- “Results-Based Management Handbook” (UNICEF, 2017)<sup>42</sup>

---

<sup>37</sup>

[https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/879438/HMT\\_Magenta\\_Book.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/879438/HMT_Magenta_Book.pdf)

<sup>38</sup>

<http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=20910&FromSearch=Y&Publisher=1&SearchText=theory%20of%20change&SortString=ProjectCode&SortOrder=Asc&Paging=10>

<sup>39</sup>

[https://www.researchgate.net/publication/297234536\\_Monitoring\\_evaluation\\_for\\_climate\\_change\\_adaptation\\_and\\_resilience\\_A\\_synthesis\\_of\\_tools\\_frameworks\\_and\\_approaches\\_-\\_Second\\_edition?channel=doi&linkId=56ddc76808aeb8b66f949d86&showFulltext=true](https://www.researchgate.net/publication/297234536_Monitoring_evaluation_for_climate_change_adaptation_and_resilience_A_synthesis_of_tools_frameworks_and_approaches_-_Second_edition?channel=doi&linkId=56ddc76808aeb8b66f949d86&showFulltext=true)

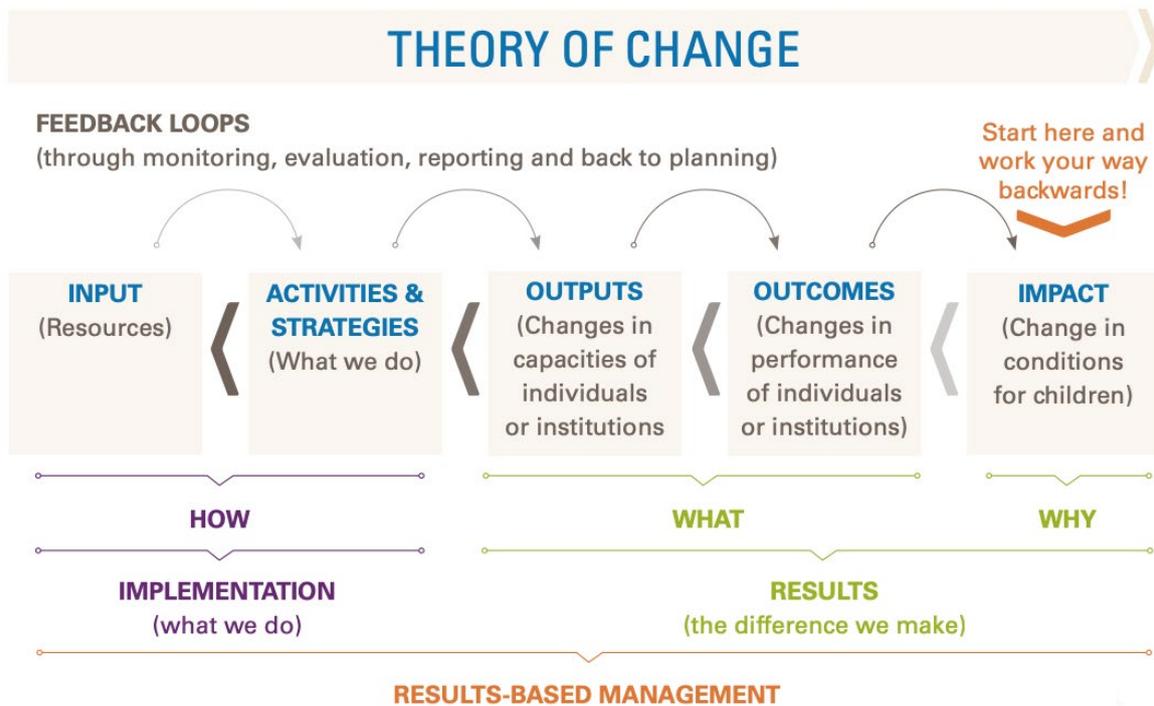
<sup>40</sup> [http://pdf.wri.org/making\\_adaptation\\_count.pdf](http://pdf.wri.org/making_adaptation_count.pdf)

<sup>41</sup> [https://www.adaptationcommunity.net/download/me/project-level-me/GIZ-2013\\_Adaptation\\_made\\_to\\_measure\\_second\\_edition.pdf](https://www.adaptationcommunity.net/download/me/project-level-me/GIZ-2013_Adaptation_made_to_measure_second_edition.pdf)

<sup>42</sup> <https://www.unicef.org/rosa/media/10356/file>

The UNICEF publication includes a useful snapshot of results based managed framed against the Theory of Change which provides a good introduction to how the Theory of Change can support the line of sight between investment decisions and actions, and investment outcomes and impacts.

A snapshot : Results-based Management and the Theory of Change (Source UNICEF, 2017)



Use of the Theory of Change can be time consuming if undertaken in a participatory manner. However, based on the common use of the approach in related fields, proportionate use of ToC (or similar practices) can cost-effectively support a managed adaptive approach to flood risks management.

© Published by Rivelin Bridge Ltd 2022 on behalf of ClimateXChange. All rights reserved.

While every effort is made to ensure the information in this report is accurate, no legal responsibility is accepted for any errors, omissions or misleading statements. The views expressed represent those of the author(s), and do not necessarily represent those of the host institutions or funders.



Scotland's centre of expertise connecting climate change research and policy

✉ info@climatexchange.org.uk  
 ☎ +44(0)131 651 4783  
 🐦 @climatexchange\_  
 🌐 www.climatexchange.org.uk

ClimateXChange, Edinburgh Climate Change Institute, High School Yard, Edinburgh EH1 1LZ